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FINAL REPORT

ASBESTOS IN BUILDINGS

NATIONAL SURVEY OF ASBESTOS-CONTAINING FRIABLE MATERIALS

by

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DISCLAIMER

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ASBESTOS IN BUILDINGS NATIONAL SURVEY
OF ASBESTOS-CONTAINING FRIABLE MATERIALS

EXECUTIVE SUMMARY

The U. S. Environmental Protection Agency's Office of Toxic Substances (OTS) has an ongoing program concerning asbestos in buildings. As part of this program, a national survey of materials in buildings was conducted. The survey was an effort to deal with the broad problem of public exposure to asbestos-containing friable materials. Previous estimates of the number of buildings that contain asbestos ranged from 5 to 45 percent with an unknown degree of accuracy because they were based on anecdotal information or expert opinion. No valid national estimates had been generated and this wide range did not satisfy the Agency's information needs. Thus, a national survey was undertaken to produce more precise and statistically valid estimates with a known degree of accuracy that can be used to support OTS' technical assistance and regulatory programs.

The survey's primary objective was to determine the extent of the use of friable asbestos-containing materials in buildings and the amount of asbestos in them. A secondary objective was to determine how many buildings have asbestos-containing floor and ceiling tiles and the approximate square footage of each. To accomplish these objectives, the survey was designed to: (1) estimate the number and percent of buildings with asbestos-containing friable material; (2) estimate the square footage of such material; and (3) estimate the percent asbestos content of the material. The estimates were to be made at specified levels of accuracy, and estimates of their precision were also to be made. These estimates were made for three types of buildings: Federal government (owned or operated by a civilian agency);

residential (with 10 or more rental units); and private nonresidential (largely commercial--office, retail and other). Additional information was gathered including data on ceiling tile, pipe or boiler insulation, floor tile and building characteristics.

The survey involved five major areas of work: the development of a survey design, the design and implementation of a quality assurance program, the execution of a field survey, the laboratory analysis of field samples, and the statistical analysis and interpretation of the data.

The study was conducted in 10 sites (cities or groups of counties) chosen with probability sampling to represent the continental U.S. A total of 231 buildings was inspected, with about half being private nonresidential, one-quarter residential, and one-quarter Federal government. A total of 1,514 bulk samples were taken. The sample of buildings was chosen so that separate estimates could be made for each type of building. Although survey participation was not mandatory, a high rate of cooperation was achieved -- 88 percent of initially sampled eligible buildings were inspected. Replacements for those buildings that did not participate were identified and substituted.

Each sampled building was thoroughly inspected for the presence of materials which might contain asbestos: sprayed- or trowelled-on friable materials, ceiling tile, pipe and boiler insulation, and vinyl floor tile. A bulk sample was taken of any such material found, and all bulk samples except floor tile samples were analyzed for asbestos content. Pipe wrap was sampled at elbows, pipe ends and damaged spots, to estimate asbestos content of exposed material. Undamaged material not at elbows or valves may have lower percent asbestos content. The analysis was carried out using Polarized Light Microscopy; the identity of the fibers was determined by optical characteristics according to an established protocol. Vinyl floor tile was sampled whenever found. The results of those analyses are not yet available, and will be presented in a separate publication. During the building inspection, auxiliary data such as date of construction and number of floors was also recorded.

The major study findings are summarized below. The term asbestos-containing friable material refers collectively to sprayed- or trowelled-on friable material, ceiling tile, and/or pipe and boiler insulation. Results pertaining to one of these types of material specifically reference the particular material type. The term "all buildings" refers to estimates based on survey data appropriately weighted to the defined target universe. There are two important exclusions from this universe. One is primary and secondary schools, which are studied and regulated under a separate EPA program. The other excluded buildings are those owned or occupied primarily by agencies of State or local governments, which may be a sizable number of buildings (there are no published estimates of the exact number).

The figures given here are estimates and, as such, are imperfect measures. In general, survey estimates are subject to sampling error and nonsampling error. Ranges given in parentheses following estimates represent the 95 percent confidence limits for the estimates due to sampling error. This means that there is only a five percent chance that actual values fall outside of this range. Potential sources of nonsampling error are discussed in Section 3.

- About 20 percent (14-27 percent) of all buildings have some type of asbestos-containing friable material. This represents 733,000 (499,000-966,000) buildings.

- Five percent (0.5-10 percent) of buildings have asbestos-containing sprayed- or trowelled-on friable material, accounting for 192,000 (18,000-365,000) buildings.

- Sixteen percent (6-25 percent) of buildings, or 563,000 (239,000-888,000) buildings have asbestos-containing pipe and boiler insulation. This material is generally limited to closed, restricted-access areas rather than offices or other highly-used space.

- The amount of sprayed- or trowelled-on asbestos-containing material is estimated at 1,184 million square feet (406-1,961 million square feet).

- The average percent asbestos content (weighted by square footage of material) in asbestos-containing sprayed- or trowelled-on friable material was 14 percent (7-21 percent). For asbestos-containing pipe and boiler insulation material, the average percent asbestos content was 70 percent (66-74 percent).

- Rental residential and Federal government buildings had a higher incidence of asbestos-containing friable materials than private nonresidential buildings. These two types of buildings account for 11 percent of the total population of buildings.

- Very few buildings had asbestos-containing ceiling tile (less than 0.5 percent of buildings). The square footage of asbestos-containing ceiling tile is also low, an estimated 3.6 million square feet (less than 7.8 million square feet), and the average asbestos content of the asbestos-containing ceiling tile that was found was quite low, averaging three percent (less than 8 percent).

- Buildings built in the sixties are more likely to have asbestos-containing sprayed- or trowelled-on friable material (15% of such buildings do), than other buildings. It appears that the extensive use of asbestos-containing sprayed-on friable material would have continued and perhaps increased in the 1970's had not the EPA banned the use of those materials for all but decorative purposes in 1973. In 1978, the EPA banned all other uses of these materials. Older buildings are more likely than newer ones to have asbestos-containing pipe and boiler insulation.

- No significant differences in percent asbestos content were found by building height or construction type (masonry, frame, or steel beam).

The quality assurance program covered all aspects of the study. Personnel working on the study were chosen for their qualifications and experience and were given specific training in survey tasks. Protocols and manuals were prepared and followed for every aspect of the work. The fieldwork was conducted with extensive telephone supervision and site visits. The laboratory analysis had both internal and external laboratory checks with excellent agreement.

SECTION 1

INTRODUCTION

I. BACKGROUND

Asbestos-containing materials have been widely used in building construction. Some of these materials are friable, that is, they may be crumbled, pulverized, or reduced to powder by hand pressure. When friable material is present, asbestos fibers may be easily dislodged and become airborne. People using the building are then exposed to the risk of breathing asbestos fibers, which research indicates is associated with increased incidence of cancer and respiratory diseases. The EPA has responded to this situation in several ways. Under the Clean Air Act, EPA restricted the use of sprayed-on asbestos-containing friable materials except for decorative purposes in new construction as of 1973, and banned the use of all sprayed-on asbestos-containing friable materials in new construction beginning in 1979. Under the Toxic Substances Control Act, EPA promulgated the Asbestos-in-Schools Identification and Notification Rule in 1982, as part of a program to protect the nation's school children from this potential health hazard.

The Asbestos in Buildings National Survey of Asbestos-Containing Friable Materials is part of an effort to deal with the broader problem of public exposure to asbestos from friable building materials. Such exposures might occur in the office, in a commercial establishment, in a Federal government building or in a rental apartment building. In 1982, a report prepared by GCA Corporation summarized the available data on the presence of asbestos-containing friable materials in public and commercial buildings (Anderson, et al. 1982).* That study combined a review of the existing literature with a telephone/mail effort to gather the results of inspections and analyses already performed by building owners and managers. The respondents were largely government and university sources, providing very little data about commercial buildings. That effort resulted in an estimate that 5 percent of buildings built before 1979 had friable asbestos material. The study also canvassed the expert opinions of architects, construction engineers, building inspectors, and others concerning the number of buildings they would estimate had friable asbestos material. The consensus of those canvassed was that nearly half of buildings built between 1946 and 1973 contained friable asbestos material. Thus available expert opinion and anecdotal evidence, primarily about publicly-owned buildings, presented widely diverging estimates (5 percent to 45 percent) with an unknown degree of accuracy. In order to make decisions as to the seriousness of potential exposure, more objective data were needed. Therefore, the present study was undertaken to obtain valid, national estimates with a known degree of accuracy and a common definitional basis from a statistical survey.

The data presented in this report are based on a sample survey. Advantages of such data include: a defined target universe to which estimates apply; specified and uniform building inspections, definitions, and decisions as to material being studied; controlled laboratory analyses with an explicit quality control plan; and the ability to measure the variance of the estimates due to sampling.

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*Anderson PH, Bell RK, Huidobro P, Bergson EF, and Sawyer RN. 1982. GCA Corp./Technology Division. Asbestos in Public and Commercial Buildings. Draft Final Report, Washington, D.C.: Office of Pesticides and Toxic Substances, U.S. Environmental Protection Agency. Contract 68-01-5960.

Like all survey data, the estimates are subject to sampling error, which has been estimated from the survey data and is presented in terms of 95 percent confidence limits for important estimates. Some readers may find the confidence bounds in this survey to be too wide for their purposes. The level of precision necessary for EPA policy-making purposes was specified in advance and this pre-specified accuracy was achieved. The decision is discussed more thoroughly in Section 3. Further, the statement that 5 percent (0.5 to 10 percent) of buildings have asbestos-containing sprayed- or trowelled-on friable material is much more precise than the GCA findings discussed above, and does not suffer from reliance on anecdotal evidence and opinion.

The data will also be subject to nonsampling error, such as potential bias introduced by substitution of buildings, inspection or laboratory error, and errors in data collection, transcription, keypunching, etc. The Quality Assurance Plan provided ways of guarding against such errors and in some cases measures of the extent of such errors. There is no evidence that nonsampling errors have contributed any substantial bias to the estimates. In particular, substitution of buildings, a potential source of nonsampling error, was minimal because of the excellent response rate of the original sample (88 percent).

II. OBJECTIVES

The primary objective of this study was to obtain more objective data to determine, within a stated level of accuracy, the extent to which asbestos-containing friable materials are present in public and commercial buildings. Specifically, through on-site inspections of a nationally representative sample of buildings, estimates were planned for:

- Number of public and commercial buildings which have asbestos-containing friable materials;

- Square feet of the material in such buildings; and
- Percent of asbestos in the material.

The statistical analysis plan included separate estimates for:

- Privately-owned, nonresidential buildings;
- Federally owned or leased buildings;
- Rental apartment buildings with 10 or more dwelling units;
- All nonresidential buildings; and
- All buildings combined.

A second set of estimates was planned to elaborate on the primary results. The three basic estimates were to be tabulated separately for various types of materials:

- Sprayed- or trowelled-on friable materials;
- Ceiling tile;
- Pipe wrap and insulation found in machine rooms; and
- All materials combined.

Estimates were also planned based on vinyl floor tile findings (these results will appear in a separate report). Separate estimates were planned for sprayed- or trowelled-on friable material and ceiling tile which is directly exposed in areas of the building outside of machine rooms. Data on auxiliary building characteristics were also collected, and estimates by construction date, height and construction type were planned. Regional estimates or comparisons were not planned, since the sample was not large enough to allow for separate estimates by region.

As part of the objective of providing quantitative estimates, the estimation of the probable size of error due to sampling in the most important estimates was also included in the statistical analysis plan. Thus the estimates are accompanied by estimated confidence intervals.

III. OVERVIEW OF REPORT

In this report we present the results of the Asbestos in Buildings National Survey of Asbestos-Containing Friable Materials. The main results are summarized in Section 2. Section 3 reviews the Quality Assurance program of the study and its results. Section 4 describes the building sample design and building selection. Section 5 describes the procedures used in the field, and Section 6 describes the analysis of the bulk samples. Section 7 contains extensive tables and discusses the quantitative findings of the survey in detail. Section 8 contains a qualitative interpretation of the data collected in the survey, with subjective comparisons made regionally as well as urban versus rural comparisons. Finally, several appendices provide details which were too lengthy or too technical to include in the body of the report.

The results from floor tile analyses are not contained in this report and will be presented in a separate document.

SECTION 2

CONCLUSIONS

The major findings of this survey are the national estimates made from the data. These are presented in tabular form, along with statements based on the data. The numbers are statistically unbiased estimates based on a national probability sample, and represent a sample estimate of the result that would be obtained from a census of the target universe in which standard inspection, bulk sampling and chemical analysis was conducted for all buildings in the target universe. The size of the difference between sample results and results from such a hypothetical census are measured by sample variances estimated from the survey data. Thus the accuracy of the figures can be objectively assessed.

Estimates are given together with 95 percent confidence limits in parentheses. These confidence limits are based on the sampling variances estimated from the survey data. (The estimation procedures are discussed in Section 7 and Appendix F.) The limits can be expressed as the following statements. For the first entry in Table 2-1 for all buildings, which is 192 (18-365) thousand, one would say, "It is estimated with 95 percent confidence that the number of buildings with asbestos-containing sprayed- or trowelled-on friable material is between 18,000 and 365,000 buildings, with a point estimate of 192,000 buildings." When an upper limit is given, as in the upper left corner of Table 2-1, where the entry is 5 (less than 10) thousand, this indicates that while asbestos was found in some buildings in the survey sample, the lower bound of the confidence interval is a small number. The statement for this estimate would be, "It is estimated with 95 percent confidence that the number of Federal government buildings with asbestos-containing sprayed- or trowelled-on friable materials is less than 10,000 buildings, with a point estimate of 5,000 buildings." This means that there is a 5 percent chance that actual values fall outside of this range.

The major findings are given in Tables 2-1 through 2-4.

- Table 2-1 gives the estimated number of buildings with asbestos-containing friable material by type of material and type of building. The estimated number of buildings with any type of asbestos-containing friable material is 733,000 buildings, with a 95 percent confidence interval of 499,000 to 966,000 buildings.

Table 2-1. Estimated number of buildings with asbestos-containing friable materials by type of material and type of building (in 1,000s) (95% confidence limits are provided for each estimate)

Type of building (universe total)	Type of asbestos-containing friable material			
	Sprayed- or trowelled-on	Ceiling tile	Pipe/boiler insulation[c]	Any material
Federal government 35	5 (< 10)	1 (< 2)	9 (< 18)	14 (8-20)
Residential (10+ rental units) 350	64 (34-94)	2 (< 6)	155 (66-243)	208 (119-297)
Private nonresidential 3,221	122 (< 275)	0[a]	400 (76-724)	511 (274-748)
All buildings[b] combined 3,606	192 (18-365)	2 (< 6)	563 (239-888)	733 (499-966)

[a] Of 110 sampled buildings in this category, none had asbestos-containing ceiling tile. However, some small number of buildings in this category may have asbestos-containing ceiling tile.

[b] May not equal sum of the columns due to rounding.

[c] Sampled damaged or exposed material.

- In Table 2-2 these numbers are given as percentages of the total for each type of building. Overall, 20 percent (14-27%) of all buildings have some type of asbestos-containing friable material.

Table 2-2. Estimated percent[a] of buildings with asbestos-containing friable materials by type of material and type of building (95% confidence limits in parentheses)

Type of building	Type of asbestos-containing friable material			
	Sprayed- or trowelled-on	Ceiling tile	Pipe/boiler insulation[c]	Any material
Federal government	16% (< 33%)	2.0% (0.3-3.6%)	25% (8-41%)	39% (29-48%)
Residential (10+ rental units)	18% (10-27%)	0.5% (< 1.7%)	44% (26-62%)	59% (45-74%)
Private nonresidential	4% (< 9%)	0[b]	12% (2-22%)	16% (9-23%)
All buildings combined	5% (0.5-10%)	0.1% (< 0.2%)	16% (7-25%)	20% (14-27%)

[a]May not equal percentages calculated directly from Table 2-1 due to rounding in Table 2-1 and in this table.

[b]Of 110 sampled buildings in this category, none had asbestos-containing ceiling tile. However, some small number of buildings in this category may have asbestos-containing ceiling tile.

[c]Sampled damaged or exposed material.

- Table 2-3 gives the estimated square footage of asbestos-containing sprayed- or trowelled-on friable material and asbestos-containing ceiling tile. While 1.2 billion square feet of asbestos-containing sprayed- or trowelled-on friable material is estimated to be in buildings, very little asbestos-containing ceiling tile was found (less than 7.8 million square feet).

Table 2-3. Estimated square footage of asbestos-containing friable materials by type of material and type of building (in 1,000,000s) (95% confidence limits in parentheses)

Type of building	Type of asbestos-containing friable material	
	Sprayed- or trowelled-on	Ceiling tile
Federal government	71 (< 165)	2.0 (< 4.6)
Residential (10+ rental units)	537 (203-870)	1.6 (< 5.2)
Private nonresidential	576 (< 1,480)	0[a]
All buildings combined	1,184 (406-1,961)	3.6 (< 7.8)

[a]Of 110 sampled buildings in this category, none had asbestos-containing ceiling tile. However, some small number of buildings in this category may have asbestos-containing ceiling tile.

- Table 2-4 gives the average percent asbestos content in the various types of asbestos-containing friable material. Pipe and boiler insulation shows the highest asbestos content, 70 percent (66-74 percent), followed by sprayed- or trowelled-on friable material with 14 percent (7-21 percent). The asbestos-containing ceiling tile that was found had very low asbestos content, 3 percent (less than 8 percent).

Table 2-4. Estimated average percent asbestos content[a] in asbestos-containing friable materials by type of material and type of building (95% confidence limits in parentheses)

Type of building	Type of asbestos-containing friable material		
	Sprayed- or trowelled-on	Ceiling tile	Pipe/boiler insulation[c]
Federal government	29% (23-36%)	3% (< 11%)	55% (46-63%)
Residential (10+ rental units)	9% (1-17%)	2% (< 5%)	67% (56-79%)
Private nonresidential	17% (< 33%)	--[b]	71% (62-80%)
All buildings combined	14% (7-21%)	3% (< 8)	70% (66-74%)

[a]Average percent asbestos weighted by square footage of material (except pipe/boiler insulation unweighted).

[b]Of 110 sampled buildings in this category, none had asbestos-containing ceiling tile. Therefore, percent asbestos content could not be estimated for this cell.

[c]Sampled damaged or exposed material.

To supplement these tables we present some general observations based on these tables and others presented in Section 7.

- Rental residential buildings have the highest incidence (18% or 64,000 buildings) of sprayed- or trowelled-on asbestos-containing friable material although the material has a lower average percent asbestos content than in other types of buildings. This appears to be due to widespread usage of asbestos-containing decorative or acoustic trowelled-on materials in apartment buildings.

- Sixteen percent of all Federal government buildings have sprayed- or trowelled-on asbestos-containing friable material. The average percent asbestos content is much higher (29%) than for other building types.

- More buildings have asbestos-containing pipe and boiler insulation than other types of asbestos-containing materials. This is generally limited to machine rooms rather than office or other highly-used space.

- Private nonresidential buildings form 89 percent of the target universe, and most of the buildings with asbestos-containing friable materials are private nonresidential buildings.

- Virtually no asbestos-containing ceiling tile was found (less than 0.5 percent of buildings had any), and what there was had very low asbestos content (under 10 percent, averaging 3 percent).

- More buildings have asbestos-containing pipe and boiler insulation, 16 percent (7-25 percent), than asbestos-containing sprayed- or trowelled-on friable material. This material also has higher asbestos content, 70 percent (6-74 percent). (Pipe wrap was sampled in damaged or exposed areas, which may tend to have higher asbestos content due to the loss of non-asbestos binders.) This material is generally confined to machine rooms which have limited access but may be part of the building ventilation system.

- Most asbestos-containing sprayed- or trowelled-on friable material found was exposed to areas of public use rather than found behind drop ceilings or otherwise concealed.

Looking at the incidence of asbestos-containing friable materials by other building characteristics showed that:

- Prior to 1960, most of the asbestos-containing friable materials found were boiler and pipe insulation materials. After 1960 most of the asbestos-containing friable materials were sprayed or trowelled onto ceilings and steel beams. This continued until 1973, when the EPA banned the use of sprayed-on asbestos-containing friable materials for all but decorative use. These materials were banned totally in 1978.

- Small sample size precluded any conclusions being drawn on the importance of building height or construction type.

These and other observations are presented in more detail in Section 7.

SECTION 3
OVERALL QUALITY ASSURANCE PROGRAM

Quality assurance was an important part of all aspects of this study. The quality assurance program is fully described in the Quality Assurance Plan.* Quality assurance covers the organization of the project team and all aspects of project work. The major elements of the quality assurance program are summarized below.

I. PROJECT OVERVIEW

The Asbestos in Buildings National Survey of Asbestos-Containing Friable Materials was a survey of a probability sample of buildings representing the building stock of the continental US. The selected buildings were identified in the field by an advance person, who also performed part of the statistical sampling task, and a two-person team inspected each building for friable material. When such material was identified, data about the location and type of material were recorded, and bulk samples were taken. During the inspection visit, other building characteristics of interest were recorded. The bulk samples were transmitted to the laboratory for analysis of asbestos content. This laboratory analysis was carried out using Polarized Light Microscopy (PLM), a method in which bulk material is mounted on a slide, magnified and observed under polarized light using prescribed techniques. The identity of the fibers is determined by the optical characteristics observed in this way, according to an established protocol. Vinyl floor tile was sampled whenever found. The results of those analyses are not yet available, and will be presented in a separate publication.

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*Quality Assurance Plan, Asbestos in Public Buildings Survey, EPA, 1983, Contract 68-01-6721.

II. ORGANIZATION AND PERSONNEL

The study was conducted as a collaborative effort for EPA's Office of Toxic Substances (OTS) under two prime contracts. Battelle Columbus Laboratories (BCL), under EPA Contract No. 68-01-6721, was the prime contractor under contract to the Design and Development Branch of the Exposure Evaluation Division of OTS. Westat was the subcontractor to BCL under Subcontract No. A-3043(8149)-270. Midwest Research Institute (MRI), under EPA Contract No. 68-02-3938, was the prime contractor under contract to the Field Studies Branch of the same division. Its subcontractor was Research Triangle Institute (RTI), under Subcontract No. 111-7900-6.

The major tasks in the study were survey planning, quality assurance, designing and drawing the national sample of buildings, developing data collection procedures and materials, conducting a pilot study, hiring and training field inspection team members, data collection in the field (including taking bulk samples), laboratory analysis of bulk samples using PLM, data preparation, statistical analysis and interpretation and writing a final report. While BCL was responsible for the overall management of the project, Westat, under subcontract to BCL, had direct responsibility for all areas listed above with the following exceptions. MRI shared responsibility for quality assurance, supplied one building inspector directly and another through a subcontract with Research Triangle Institute (RTI), and was completely responsible for the PLM analysis of the bulk samples. MRI also assisted in writing the final report. One other subcontractor, Environmental Health Laboratory, provided quality assurance PLM analyses to MRI. The project organization and key personnel are shown in Figure 3-1.

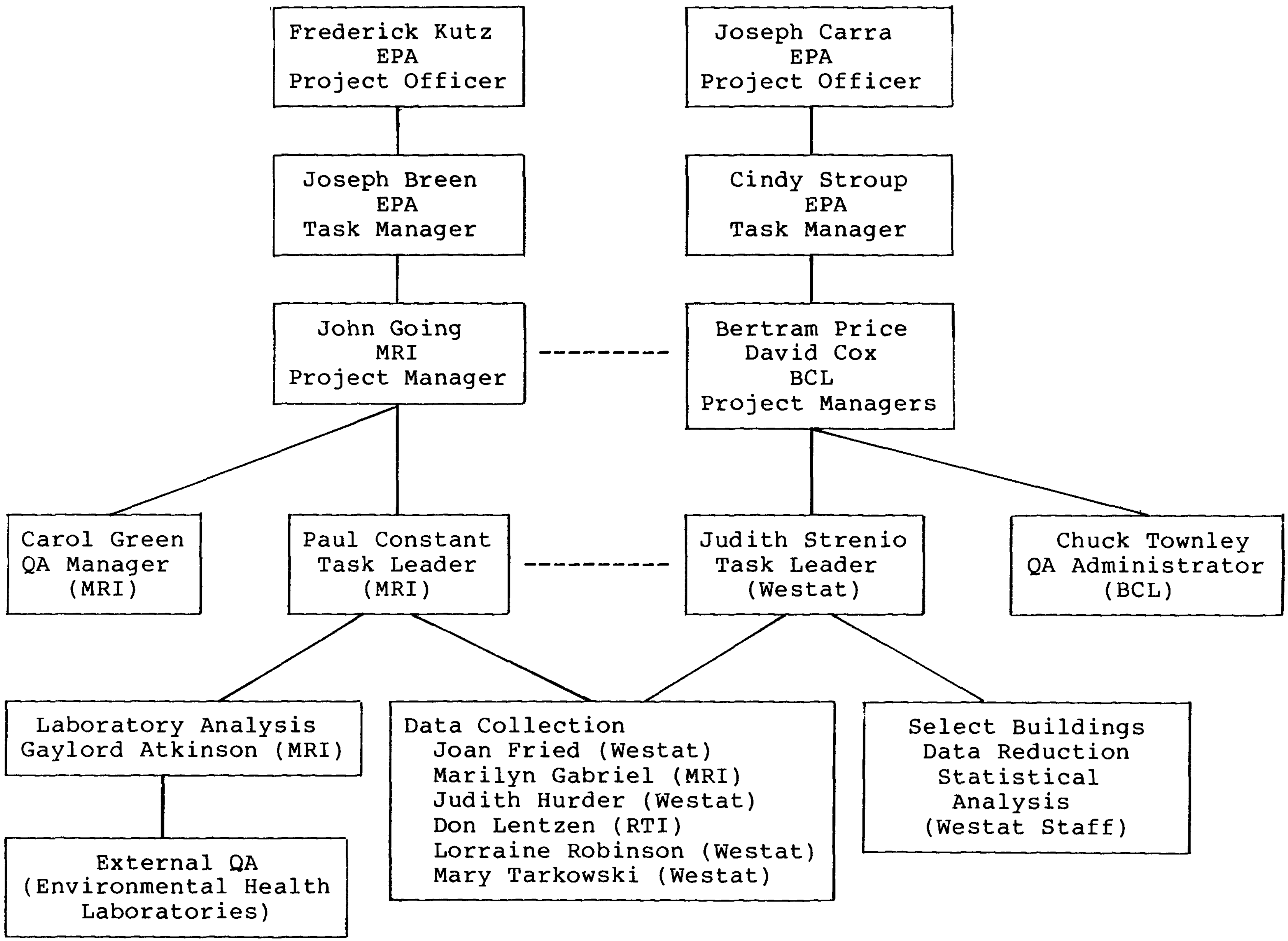

Figure 3-1. Asbestos in buildings survey project organization

III. OPERATION

Every aspect of project operations is subject to quality assurance (QA) considerations. Such measures as thoroughly reviewing all work and assuring that all project personnel have adequate experience and training for their project responsibilities were followed throughout the course of the work. Some aspects of the project work, however, had specific quality assurance procedures, which are summarized in this section.

A. Protocols

Several elements of the collection of data followed specific protocols in order to assure uniformity of sampling and results. Instructions for inspecting each building, completing the building data forms, determining where to take bulk samples, and taking the bulk samples are contained in the Field Manual. They are described in Section 5 of this report, and the relevant chapters of the Field Manual form Appendix A. The actual data forms are given in Appendix B. Instructions for taking side-by-side samples for QA purposes at every tenth sample were also contained in the Field Manual. These instructions are included in Appendix A. Instructions for transmitting the bulk samples to MRI are also given in the Field Manual. The bulk samples were analyzed for asbestos according to the protocol presented in Appendix C.

B. Training

The building inspection teams and the advance person attended a three-day training session at Westat. The building inspectors were selected based on their extensive previous experience with EPA-sponsored asbestos projects. They did not need as much training in inspections as inexperienced inspectors would have required. The training agenda is shown in Appendix D. The PLM analysts also received appropriate training, as specified in the Quality Assurance Plan.

C. PLM Quality Control Data

For the PLM analysis, a one-in-ten randomly selected sample of side-by-side bulk samples was taken for quality control purposes. For half of the pairs, both samples were analyzed blind at MRI for project internal quality control; for the remaining pairs, one sample was analyzed at MRI and one sample was analyzed at Environmental Health Laboratory for project external quality control. In addition, MRI conducted its own quality control analysis of ten percent of the samples. The project quality control results are presented in this section. The internal MRI quality control results are reported in detail in Section 6.

1. Project Internal Quality Control

For internal quality control, 43 pairs of samples were analyzed at MRI. The two blind analyses agreed in 98 percent of these pairs (42 agreements). Laboratory results on the issue of whether asbestos was present in a given sample were reported as one of three categories: none detected, trace (less than 1 percent), and greater than or equal to one percent. In the statistical analysis, samples in the first two categories were counted as not having asbestos, while those in the third category were counted as positive for asbestos. Therefore, in the analysis of quality control results, none detected and trace (less than 1 percent) are in agreement, as shown in the tables

Table 3-1. Internal QA results: both samples in a pair analyzed at MRI

Type of material	Both <1% or N.D.[a]	Both ≥1%	No discrepancy		Discrepancy	Total pairs
			Number	Percent		
Sprayed- or trowelled-on friable material	6	5	11	92%	1[c]	12
Ceiling tile	13	0	13	100	0	13
Pipe wrap[b]	5	13	18	100	0	18
Total Pairs	24	18	42	98%	1	43

[a] N.D. = none detected, i.e., no asbestos detected. Trace (<1%) was also reported, and is equivalent to N.D.

[b] Includes any pipe wrap, insulation or sprayed- or trowelled-on friable materials found in boiler rooms, as well as pipe wrap and non-friable insulation found outside boiler rooms.

[c] Originally, one sample's analysis showed 1% and the other's "none detected." After reanalysis, both showed 1%.

presenting the results. The data are summarized in Table 3-1, where the results for sprayed- or trowelled-on friable material, ceiling tile, and pipe wrap and other insulation are shown separately. For sprayed- or trowelled-on friable material, agreement was found in 11 out of 12 pairs, or 92 percent. For ceiling tile, agreement was 100 percent -- 13 out of 13 pairs agreed. For pipe wrap and other insulation, there was also 100 percent agreement -- 18 out of 18 pairs agreed. As noted in the table, the discrepancy was between "none detected," and "1%", which is close to the technical limits of PLM analysis' ability to detect asbestos. After blind reanalysis of the discrepant pair, 100 percent agreement was reached. Thus, the internal quality control results show a high standard of analysis.

2. Project External Quality Control

For external QA, 44 pairs of samples were analyzed. One sample of each pair was analyzed at MRI and the other at Environmental Health Laboratory (EHL). The two analyses agreed for 98 percent of the pairs (43 agreements). The data are summarized in Table 3-2, where the results for sprayed- or trowelled-on friable material, ceiling tile and pipe wrap and other insulation are shown separately. For sprayed- or trowelled-on friable material, agreement was found in 12 out of 12 pairs, or 100 percent. For ceiling tile, agreement was also 100 percent -- 13 out of 13 pairs agreed. For pipe wrap and other insulation there was 95 percent agreement -- 18 out of 19 pairs agreed. The discrepancy showed "none detected" from MRI and 7 percent asbestos from EHL. Reanalysis by MRI showed 1 percent asbestos. Thus, after reanalysis, the agreement rate was 100 percent, and the external quality control results are further evidence of the excellent reliability of the laboratory analyses results.

Table 3-2. External QA results: one sample of each pair analyzed at MRI, the other at Environmental Health Laboratory

Type of material	Both <1% or N.D.[a]	Both ≥1%	No discrepancy		Discrepancy	Total pairs
			Number	Percent		
Sprayed- or trowelled-on friable material	7	5	12	100%	0	12
Ceiling tile	13	0	13	100	0	13
Pipe wrap[b]	3	15	18	95	1[c]	19
Total Pairs	23	20	43	98%	1	44

[a]ND = none detected, i.e., no asbestos detected. Trace (<1%) was also reported, and is equivalent to N.D.

[b]Includes any pipe wrap, insulation or sprayed- or trowelled-on friable material found in boiler rooms, as well as pipe wrap and non-friable insulation found outside boiler rooms.

[c]Original analysis showed MRI = ND, EHL = 7%. Reanalysis of MRI sample showed 1%, so both became "≥1%."

D. Statistical Reliability and Data Accuracy

The data presented in this report are based on a sample survey. In common with all survey data they are subject to sampling error as well as nonsampling error. These two types of error are discussed below. Before presenting that discussion we review the advantages of the data collected in a survey over anecdotal evidence, expert opinion, and attempted complete enumerations which include a very low percent of the universe.

The advantages of survey-based data can be summarized by the statement that one knows what the final estimates represent. Specifically, the universe of buildings to which the estimates apply can be stated; the type of inspection conducted is specified and uniform; the type of material of interest is likewise specified and uniform; the same data items are collected for all selected buildings using common definitions; the laboratory analyses are conducted in a known fashion with specified quality control procedures; the tabulations are made using established definitions and the level of precision of the estimates can be measured by estimating the sampling error from the data. A further advantage in the present survey was that the precision of the estimates was roughly estimated in advance, so that a decision could be made at the outset as to the most efficient survey design in terms of precision of estimates versus survey cost. The level of accuracy of the present survey, then, was thoughtfully chosen as adequate to meet the EPA's policy-making information needs. Further, the measured (known) precision of the current survey leads to a 95 percent confidence interval which is much narrower than the range of previous estimates, which did not have a known or measured precision, and which were subject to several serious potential sources of bias.

1. Survey Design Considerations

Once it was decided that a probability sample of buildings would be inspected to produce national estimates, several options were considered in terms of the scope of the survey versus the level of resources required. Several tradeoffs were looked at in designing the study. The specific decisions made involved three issues: the definition of the target universe; detailing the types of buildings for which separate estimates were desired; and the level of accuracy of the national estimates. These three issues are discussed in the sections below.

a. Definition of Target Universe

The initial objective of the asbestos in buildings survey was to survey "all public buildings." This goal required further definition before it could be operational. Sampling frames were available at moderate cost for commercial establishments and Federal government owned or occupied buildings. Census data on number of dwelling units in buildings with ten or more units was available to use in drawing a sample of small areas in which rental apartment buildings could be listed in the field, again at moderate cost and without adding excessive time to the schedule. The only major type of public building not included in these frames are buildings primarily owned or occupied by State and local government agencies. No adequate frame of such buildings exists. The effort required to develop such a frame was judged to be excessive in terms of the contribution to the total estimate one might anticipate from such buildings. Although no specific data are available as to the number of State and local government buildings, a maximum can be estimated from DOE survey data.* Starting with the DOE estimate of the total building stock, one

*The best currently available data on the U.S. building stock was obtained in a survey for the U.S. Department of Energy. Data discussed here are from Nonresidential Buildings Energy Consumption Survey: Building Characteristics. U.S. Department of Energy, 1981, DOE/EIA-0246.

subtracts the estimated number of vacant buildings, warehouses, primarily residential buildings, and private nonresidential buildings. The remaining buildings consist of 95,000 buildings, which represents a maximum estimate of the number of State and local government buildings. This would represent 2.5 percent of the total, if included. Thus, even if such buildings were more likely to contain asbestos than the surveyed buildings, they could not change the overall estimated percent of buildings with asbestos by more than 2.5 percentage points.

b. Separate Estimates for Building Types

In order to make separate estimates for a particular type of building, a sufficient number of such buildings must be sampled. If the subgroup is a small proportion of the target universe, it will have to be oversampled--that is, sampled at a higher rate than buildings not in the subgroup. Sampling groups at different rates leads to a difference in statistical weights which can result in a larger sample variance for the overall estimates than would be achieved by a sample of the same size with a uniform sampling rate. The tradeoff is between either expanding the sample (and increasing the survey cost), accepting a larger sample variance for the national estimates, or not requiring oversampling of certain subgroups. The final decision in terms of subgroups was to sample so as to get estimates for Federal government, rental residential and commercial buildings separately. Other types of buildings were considered as candidates for separate estimates but finally rejected because the need for such detail did not justify the costs involved. At the total sample size finally selected, the oversampling required to make separate estimates for Federal and residential buildings had the effect of increasing the width of 95 percent confidence limits on national totals by about 25 percent.

c. Precision of Estimates of National Totals

The third major tradeoff concerned the precision of the overall estimates (as measured by the projected width of the confidence limits) versus the cost of the survey. For a given set of target groups, a larger sample size will yield estimates with greater precision, and will add to the cost of the survey. The level of effort selected was deemed by EPA to provide sufficient precision to support the policy decisions with which they were faced. It would be inefficient to spend more for greater precision which was not necessary. The projected width of 95 percent confidence limits on the statistic "number of buildings with asbestos-containing sprayed- or trowelled-on friable material" was ± 200,000 buildings, while the actual confidence limits achieved by the survey for that statistic were ± 175,000. Thus, although the intervals are too wide for many purposes, they have achieved or exceeded the desired level of accuracy for the EPA program managers.

This decision is put into perspective when the estimate considered is percent of buildings with such material. The survey confidence limits are 0.5%-10%; whereas the previously available estimates ranged from 5% to 45%, with no information to evaluate the accuracy of these numbers, and serious questions of potential bias.

2. Response Rates

An important aspect of the validity of survey data is the response or cooperation rate achieved. The initial sample, drawn from a universe frame using probability sampling methods, is an unbiased probability sample of that frame. Estimates derived from the full sample are unbiased estimates. In a voluntary survey such as the asbestos in buildings study, one does not generally achieve full participation, as some contacts exercise their right to refuse participation. In this study a fairly high cooperation rate of 88 percent was achieved. Table 3-3 shows the number of buildings in the initial sample and the number and percent of those that were inspected, by sample category. As is shown in the table, all Federal government agencies approached cooperated with the survey. Among privately-owned buildings (including apartment buildings), 83 percent were cooperative, an excellent rate.

Table 3-3. Response rates for the initial sample

Type of building	Initial sample	Inspected	
		Number	Percent
Federal government	66	66	100%
Rental apartments	57	48	84
Private non-residential	110	91	83
Private residential and non-residential	167	139	83
Total	233	205[a]	88%

[a] Through substitution for non-cooperating buildings, the final sample size was 231.

Reasons for noncooperation included cases where absentee owners could not be contacted within the survey time frame, owners who would not be available to accompany inspectors during the study period, and contacts who were personally opposed to government survey work. Non-cooperation did not appear to be related to the presence or absence of asbestos-containing friable material in the building. Thus, the nonresponse that was encountered probably did not introduce any substantial bias into the survey results. In order to maintain the desired sample size, substitutions were made for non-cooperating buildings. Substitutes were chosen from the sampling frame by taking the next building on the list, thus ensuring a building as similar as possible to the originally sampled building, at least in terms of sample stratification variables.

3. Other Potential Sources of Nonsampling Error

Nonsampling errors are those which result from sources other than that attributable to sampling. There were various potential sources of nonsampling error in this survey. Although the impact of such errors on the estimates is not generally quantifiable, it is important to acknowledge these sources so that users of the survey data may be aware of their possible effects.

Potential sources of nonsampling errors include: nonresponse bias (discussed above under Response Rates); failing to sample potentially asbestos-containing material; errors in laboratory analysis of bulk samples; and errors in data collection, transcription, keypunching, or computer manipulations. The Quality Assurance Plan addresses each of these potential sources of error. Although such errors may still have occurred, there is no evidence to suggest that they introduced bias into the survey results. What evidence we do have, as detailed throughout this section of the report, indicates that such errors did not occur, or if they did, it was at a very low level.

E. Verification Procedures

A number of verification procedures were employed during the conduct of the study to ensure that the final data tape was an accurate portrayal of the desired information. These procedures included observations of the work in the field, receipt control of data forms and bulk samples, both clerical and computer data editing procedures, data retrieval activities, and final "reasonableness" checks of the data base.

1. Site Visits

A total of 6 of the 10 study sites (cities or groups of counties) had one or more observers to ensure that field procedures were being carried out correctly. This included the pretest site, which was observed by Dr. Joseph Breen and Ms. Cindy Stroup of EPA and Ms. Barbara Kreling of Westat. The first site for each team in the main study was observed by Ms. Cindy Stroup, Dr. Joseph Breen and Mr. Joseph Carra of EPA. A second site for each team was observed midway through the survey, one by Ms. Barbara Kreling of Westat and the other by Dr. Judith Strenio of Westat and Dr. Joseph Breen of EPA. The final site of the study was observed by Dr. Frederick Kutz of EPA.

2. Sample Tracing

All bulk samples taken were labeled immediately using a set of computer-printed labels of random five-digit ID numbers. Three copies of each number were used. One label went on the sample vial, one went on the building data form, with the sample location and description, and one went on the sample transmittal sheet used to send the samples to MRI. Westat staff checked the building data sheets against the transmittal sheets and MRI checked the transmittal sheets against the sample jars. Some discrepancies were found at both levels, but all but four were resolved after further investigation. Of 1,514 samples taken, only three samples were lost. Four samples listed on the building data sheets were not transmitted to MRI and were not found later. One of these was reported later by the inspector to have been a contingency sample not needed later. Therefore it had deliberately not been transmitted. This sample was removed from the data sheets. One was a side-by-side taken for QA purposes, which was replaced by splitting the main sample of the pair, which was transmitted. Thus, 99.7 percent of all samples taken were traceable.

3. Data Tape Editing

The building data and the lab data were coded, keypunched and 100 percent key verified. The resulting computer file was then edited using a computer program to check that all values fell within allowable ranges and that logical relationships between variables were not violated. For data found in error, and important variables found missing, telephone calls were made to field team members and building contacts to complete the data file, as much as possible. Any remaining missing items were given a special coded value.

4. Final Data Tape Verification

The final step in verifying the data tape was running frequencies and cross-tabulations of selected variables to check for reasonableness and consistency across all records.

SECTION 4

SAMPLE DESIGN AND SELECTION

The buildings selected for this study form a nationally representative probability sample of all buildings in the target universe. In this section the target universe is defined and the methods used to develop sampling frames are described. The actual sample design and selection process are then summarized. The sample design is given in more detail in Appendix E, along with an evaluation of frame coverage based on the experience in this survey.

I. TARGET POPULATION AND SAMPLING FRAMES

A. Target Population

The target population consisted of buildings in the continental United States falling into one of three strata, with certain general exclusions. Buildings with mixed use were classified by the majority use, which had to occupy at least half the building. The three strata are:

1. Federal government -- Owned or operated by a civilian agency of the Federal government. The building must be 50 percent or more occupied by the Federal government to fall into this category.

2. Residential (10+ rental units) -- A rental apartment building with 10 or more dwelling units. Again, a building must be 50 percent or more used as residences to fall into this category. The cut-off of 10 or more dwelling units was chosen to concentrate survey resources on buildings with the greatest potential exposure. This particular cut-off value (rather than, say, 5 or 15) was selected because the Census data from which the sample was selected report that figure separately.

3. Private nonresidential -- A privately-owned building used for nonresidential purposes. Must be 50 percent or more private nonresidential. Includes (besides commercial retail and office space) such buildings as churches, auditoriums, etc.

A standard definition of a building was used to determine the boundaries of contiguous buildings (see Appendix E) as was a standard definition of dwelling unit in defining the residential buildings.

The exclusions to the study universe follow:

1. Buildings built after January 1, 1979 -- These buildings are banned by law from containing any asbestos-containing sprayed- or trowelled-on friable materials.

2. Vacant buildings and warehouses -- These buildings were excluded because they are not generally occupied.

3. Buildings owned or operated by the military -- These buildings were not included because of difficulties in constructing a sampling frame and access to restricted areas.

4. Elementary and secondary schools -- Schools are studied and regulated under a separate EPA program.

5. State and local government buildings -- These buildings were not included because it would have been very time-consuming and costly to construct a sampling frame for them. Also, there is no reason to believe that they are different in terms of asbestos-containing materials from other buildings surveyed and adequately represented in the Federal government and private non-residential samples.

B. Sampling Frames

Each of the three target strata had a different sampling frame (i.e., list of buildings from which the sample is drawn). The three frames are discussed briefly here, and more detail is given in Appendix E.

For Federal government buildings, the 1981 General Services Administration's (GSA) Real Property Inventory (RPI) was used. Records were extracted from this list of all property owned or leased by the Federal government to form the frame. The extraction consisted of non-military, non-Army Corps of Engineers records of property listed as buildings. Buildings with primary usage of storage were excluded. The records were also extracted for the 10 sampled geographic areas to form the final frame for this stratum. Since the RPI records sometimes consist of one record for several buildings, after a record was selected, a telephone contact was made with the site building manager to list all eligible buildings from the sampled record. One of these buildings was then selected for the study.

For private nonresidential buildings, lists of business establishments were purchased from two sources, one based on credit references (the Dun's Market Indicators from Dun and Bradstreet) which has good coverage of medium-sized and large businesses and one based on Yellow Pages entries (National Business Lists) which has good coverage of smaller businesses. These lists also include some of the noncommercial establishments which are part of our target universe. The lists of establishments were sorted by address, then collapsed to one entry per address and merged into one list of addresses for each sampled ZIP code. These addresses formed the frame for private nonresidential buildings.

For residential buildings, no lists of rental apartment buildings with 10 or more units was available. Therefore an area sampling approach was taken. For each geographic area in the study, a sample of blocks or Census Enumeration Districts (in rural areas) was drawn using Census data on number of buildings with 10 or more units. The advance person went to each sampled block and located all buildings on the block which met the study definition of residential. Every eligible building was listed, together with a measure of size (number of apartments). The listing for all blocks in one area was the sampling frame for residential buildings for that area.

II. Sample Design

The sample of buildings was drawn in a three-stage stratified, clustered design. The three stages of selection were geographic areas (known as Primary Sampling Units, or PSU's), segments, and buildings, with the PSU's and segments forming clusters. The strata were the three types of buildings: Federal government, residential and private nonresidential. The target sample sizes for each stratum are shown below.* The number of PSU's to be drawn was 10.

Stratum	Target Sample Size
Federal government	56
Residential	56
Private nonresidential	112
TOTAL	224

*The number of buildings actually sampled was different from the target sample size due to a slightly different sample design in the pilot site and a frame shortfall for residential buildings in two main study sites. The final number of buildings inspected was 231 - 66 Federal government, 55 residential, and 110 private nonresidential.

In designing the sample, one decision is the total sample size, which was made based on cost and precision estimates as discussed in Section 3.III.D. of this report. One must also determine the allocation of the sample between number of PSU's and number of buildings per PSU. Thus, given the target sample size of 224 buildings, one could sample 44.8 buildings in each of 5 PSU's, 22.4 buildings in each of 10 PSU's, 11.2 buildings in each of 20 PSU's, and so on. The decision was made by estimating the optimum allocation mathematically. Essentially, the relative contributions to overall sample variance from differences between PSU's (cities or groups of counties) and differences between buildings in the same PSU is compared to the relative costs of going to more PSU's versus inspecting more buildings in each selected PSU. The optimum is thus the allocation which minimizes total variance for a fixed cost. The estimates for sample design purposes for this survey showed a fairly broad optimum, from which the 10 PSU design was selected.

The actual sample of buildings was drawn in a modified probability proportional to size design. Buildings were grouped into size classes, with the target relative rates for each size class as shown. (R is the rate for the most heavily sampled group, which all other rates are relative to.)

	Size Class	Relative Sampling Rate
1.	1,000 square feet	R/20
2.	1,001-5,000 sq. ft.	R/10
3.	5,001-10,000 sq. ft.	R/5
4.	10,001-25,000 sq. ft.	R/4
5.	25,001-100,000 sq. ft.	R/2
6.	100,001 or more sq. ft.	R

In some PSU's and some strata the classes were collapsed as described in Appendix E.

PSU's were constructed as groups of counties forming metropolitan areas or groups of rural counties. Ten were selected with probability proportional to population, stratified by size category and Census Region. Thus, the final sample of PSU's consists of four large cities, one in each major Census Region; four small to moderate cities, one in each Census Region; and two groups of rural counties, one from the South Region and one from the other three Census Regions combined.

Within PSU's, the Federal government sample was selected directly from the GSA RPI frame for that PSU. Selected buildings and groups of buildings were screened for eligibility, and replacements selected for ineligible sampled records. Sampled records with multiple buildings were contacted for a list of buildings represented, and one building was selected for inspection.

For residential buildings, the second stage of selection was blocks or Census Enumeration Districts in unblocked rural areas. These were chosen with probability proportional to a measure of size based on the number of dwelling units in buildings with 10 or more units. A fieldworker (the advance person) then listed all eligible residential buildings on the selected blocks (not only having 10 or more dwelling units -- but rental units, and being built before 1979). These listings from all sampled blocks in a PSU were the residential frame for the PSU, and a sample of buildings was drawn using number of apartments in each building as a size measure.

For the private nonresidential stratum, the second stage of selection was ZIP code within PSU. For each PSU, a sample of ZIP codes was selected with probability proportional to size, where the size measure was based on the number of employees in the ZIP area, based on data from the 1980 County Business Patterns survey.

Lists were purchased for these ZIP codes, after which the clerical reduction to address lists was made. Size measures for addresses were obtained as employee size class from one of the lists, and entries from the supplemental list (where employee size was not known) were sampled at the rate for the middle size class. Buildings were sampled from the ZIP code lists.

In each stratum, replacements were drawn randomly for ineligible initial selections, and the next entry on the list was used as a backup in case of refusal. Calculation of sample weights is discussed in Section 7.

SECTION 5

FIELD SURVEY PROCEDURES

In this section the procedures followed in conducting the field survey are described. The training of the field teams, final field identification of sampled buildings, gaining cooperation of building contacts, the building inspection procedures and the bulk sampling procedures are each discussed.

I. FIELD TEAMS AND TRAINING

The field staff consisted of six people, each assigned to one of three roles. There was one advance person, three field coordinators (two principal and one backup) and two field inspectors. The advance person went to each location alone and laid the ground work for the field teams. Each field team consisted of an inspector and a coordinator (there were two teams with one backup coordinator). The coordinator assisted in the inspections and was primarily responsible for gaining access and data collection. The field inspectors had been selected for their experience and expertise in the asbestos field. Both had extensive previous experience in inspecting buildings for asbestos under EPA auspices. The training sessions focused on the specific tasks of this survey.

Prior to training, the advance person received a copy of the Advance Manual, and the field coordinators and field inspectors received the Field Manual. These were to be read before training so the training could build on some familiarity with the study procedures.

The advance person was trained separately for the most part, since her job was fairly different from the field team job. The training agenda is shown as Appendix D. Basically, the advance person spent two days (Wednesday and Thursday) of training in her tasks. On Thursday, the field team members and advance person attended an introductory session. The advance person then finished her specific training, and left for the first site. The field teams, meanwhile, went through two full days of training, learning the specific tasks required by the study, which team member was responsible for each task, reviewing and using the data forms, and learning to work together in a practice inspection session. Because the inspectors were chosen based on previous EPA experience and qualifications, less time was spent in training to do the inspections than less qualified inspectors would have required. The training session provided an opportunity for each member of the field staff to thoroughly learn the procedures of the study and for the field teams to learn to work together as teams.

II. FINAL BUILDING IDENTIFICATION IN THE FIELD

The advance person had two major tasks: listing the residential (10 or more rental units) buildings in specified area segments within the Primary Sampling Unit (PSU); and locating, verifying, and recording information on all sampled buildings and refusal substitutes. The first task is described in Section 4, under Sample Selection. We describe the second task here. The advance person was to actually locate the sampled buildings in each PSU, check that they were in-scope for the study (not built after 1979, not vacant, etc.), and create a record to aid the field team in finding the buildings. This record consisted of a verbal description on the Advance Form (such as "white stucco building on corner across 4th St. from

Sunoco station"), clearly marking the location on a map of the area, and taking one or two pictures of each building. The addresses and names of one or more establishments in the building were also recorded. The photos and written information were collected in a notebook for use by the field team and as part of the permanent record of the study.

Besides locating and recording the sampled buildings, the advance person checked that each building in the sample met the study definitions for inclusion. Substitutions were made for buildings which did not meet the definitions (for example, warehouses or vacant buildings). The advance person was provided with a list of substitutes for buildings not meeting study definitions and instructions for using this list. If the list was used up, more substitutes were drawn. For each eligible building in the sample, a refusal substitute was identified in advance. These buildings were also located, checked for eligibility, and recorded. Any ambiguities or difficulties in locating a building based on the sampling information (usually address and some identifying name) were cleared up by telephone consultation. This part of the advance work saved the field team a great deal of time upon their arrival in the PSU.

III. GAINING ENTRY

Before a sampled building could be inspected, a responsible person had to give permission for the building to be in the study. Gaining this permission is referred to as gaining cooperation or gaining entry to the building.

The approach was different for different types of building. For Federal government buildings, contacts were made well in advance of the field period. For some facilities (generally those managed by the General Services Administration), the Director of the facility or the Chief Safety Engineer agreed to participate. For others, especially United States Postal Service and Veterans Administration facilities, permission to inspect all sampled facilities was received from a national headquarters office. All eligible government facilities did cooperate and were inspected.

For privately-owned buildings, the general approach taken was to go to the building and seek permission to do the inspection immediately from a building manager or other representative of the building owner. The exceptions to this approach were buildings which could be identified in advance as housing a large business establishment. These establishments were contacted in advance by telephone in case any paperwork was needed within the company before permission was granted.

This combination of approaches, based on experience from the pilot study, worked very well. As shown in Section 3, the response rates for the initial sample of eligibles were 100 percent for Federal government, 84 percent for rental apartment buildings and 83 percent for private non-residential buildings. The overall response rate in the survey was 88 percent.

IV. BUILDING INSPECTION PROTOCOL

The building inspection protocol is given in detail in the Field Manual. It begins with information on identifying friable materials, adapted from an EPA Region VII document entitled, Asbestos Exposure Assessment in Buildings: Inspection Manual. The actual protocol for building inspection is adapted for buildings generally from the guidelines for inspecting schools given in the EPA Guidance Document (US EPA 1979). Prior to the inspection, the Building Summary Sheet was completed (all data forms are in Appendix B). The inspection began with the machine rooms, and then proceeded floor by floor from the basement to the top floor, including parking garages and rooftop equipment areas. On each floor, all floors and ceilings were observed. Ceiling materials above suspended ceilings were observed by raising ceiling tiles, using a ladder if necessary.

During the walk-through inspection, sampling areas were defined. A sampling area is the area within the building covered with one type of material of interest. One or more samples were taken from each sampling area. In this study the materials of interest were: sprayed- or trowelled-on friable material, ceiling tile, vinyl floor tile, pipe lagging, and insulation materials found in fan and boiler rooms. For sprayed- or trowelled-on friable materials, a randomization protocol was provided for choosing three to seven spots within the sampling area to obtain bulk samples. For other materials, samples were taken from accessible or inconspicuous locations.

V. BULK SAMPLING

Bulk sampling in buildings was accomplished by two different inspectors. Each inspector covered five geographic areas. The sampling was done during the period of September 1983 through January 1984, except for the pilot study that was done in July 1983 (the pretest). A total of 1,514 bulk samples were taken from the 10 sampling locations.

A. Sample Collection and Recording

Building material that was suspected of containing asbestos was sampled. This covered ceiling tile, floor tile, pipe wrap, and sprayed- or trowelled-on friable material. When these types of materials were seen in a building, a sample was taken. The manner in which the sample was taken depended on the type of material and its accessibility.

Sprayed- or trowelled-on friable material was sampled according to the procedures in the Field Manual (Appendix A) based on the EPA guidance document for the schools program.* A room containing sprayed- or trowelled-on friable material was measured and a random number table was used to select the coordinates. The sample was then obtained from the designated place. In cases where it was impossible to random sample, such as in an apartment, the appropriate number of samples according to the protocol was taken in closets and inconspicuous areas. The core, made by a hole saw blade, was placed in a small plastic vial and a preprinted label was affixed to it. A label was also affixed to Form A and the location of the sample was recorded on Form A. (All data forms are shown in Appendix B).

Pipe wrap was accessible either in a boiler room or along walls near the ceiling. This type of sample was taken at a joint or a previously torn spot. The sample was taken using a linoleum knife or hole saw and placed in a small plastic vial. Preprinted identical labels were affixed to the sample vial and to Form B for pipe wrap outside boiler room or Form C for inside boiler room (forms given in Appendix B). The form was filled

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*Chapter 2 of <u>Asbestos-Containing Materials in School Buildings: Guidance for Asbestos Analytical Programs</u> by D. Lucas, T. Hartwell and A. V. Rao, (EPA 560/13-80-017A). Office of Toxic Substances, US Environmental Protection Agency, December 1980.

out according to the building inspection protocol found in the Field Manual (Appendix A). Blanket insulation was found above suspended ceilings or along a wall. A piece of this was pulled off by hand and placed in the vial. A label was affixed to the vial and Form B and this form was filled out.

Floor tile was more difficult to sample without leaving a hole in the floor. In many instances a spare tile was used. Otherwise a broken piece of tile was sampled or a small piece was taken, using a linoleum knife, from an inconspicuous place. The sample was then placed into a small plastic vial. Due to presumed homogeneity of floor tiles based on the manufacturing process, one sample was sufficient for each type of tile found. A preprinted label was affixed to the vial and one was affixed to Form B. The exact location where the sample was taken was recorded on the form.

Ceiling tile was sampled in much the same way as floor tile. Again the manufacturing process introduces homogeneity into the material. If a spare tile was available, a small corner was broken off. If one was not available, a broken tile was sampled or a sample was taken from an inconspicuous location, i.e., by a light fixture or behind a door in a corner. If the ceiling were suspended, a tile was raised and a corner broken off the tile so that the sampled area was not visible when the tile was back in place. The ceiling tile sample was placed in a small plastic vial and affixed with a preprinted label. A label was also affixed to Form A. The location the sample was taken and other sampling information was recorded on Form A.

B. Quality Assurance Samples

A quality assurance sample was taken along with each 10th sample taken for each type of material. The quality assurance sample was taken side-by-side with the test sample, recorded, and handled in the same manner as described for the test samples.

C. Handling and Transmitting Samples

During the building inspection and sampling, the sample vials were kept in a plastic bag. After an entire building had been inspected, the vial lids were taped down and all samples placed in double plastic bags. A custody log was maintained at all times. This consisted of filling out the important information (location, date, how shipped), placing sample labels on it, describing the sample, and recording the condition of a sample. Once all the samples were accounted for they were shipped. Samples were sent to MRI by U.S. certified mail, express mail, or were hand carried.

D. Receipt Control for Bulk Samples

Samples received at MRI were checked individually against the sample transmittal logs included with each shipment. Each sample was then logged via a bound project notebook reserved exclusively for sample traceability records. In addition to the 5-digit random field ID number already affixed to a sample, each sample was given a unique 10-digit MRI internal ID number to facilitate sample traceability at MRI.

Lists of samples received in each shipment, identified by the 5-digit random field ID numbers, were then forwarded to

Westat. Any discrepancies found in the shipments (e.g., missing samples, extra samples) were noted at this time and guidance in solving them requested from Westat.

Samples were stored in a locked room at all times except when they were analyzed.

SECTION 6

POLARIZED LIGHT MICROSCOPIC (PLM) ANALYSIS OF BULK SAMPLES

A total of 1,510 bulk samples were received at MRI from the 10 sampling locations. Westat designated 965 of these samples for analysis by MRI and 44 samples for external laboratory analysis. The remaining samples, consisting mainly of floor tiles, were not analyzed.

I. METHOD OF LABORATORY ANALYSIS

The samples were analyzed according to the protocol specified in Appendix C. This protocol conforms to that given in the EPA Interim Method(1) for the Determination of Asbestos in Bulk Insulation Samples and that published as amended in the Federal Register.(2,3) The quantitation was obtained by observing the entire sample through the stereomicroscope and visually estimating the percentage of each component relative to the whole sample. The results are comparable to those obtained by 400-point count quantitation method described in the Interim Method.(1,2,3) Asbestos-containing samples with known quantities of asbestos serve as guides for maintaining the accuracy of the estimates. Visual estimation of quantity, with the aid of a stereomicroscope, is commonly used by laboratories during asbestos analyses. For the analysis, MRI used a stero zoom microscope capable of 8X to 40X magnification equipped with an external illuminator for

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[1] USEPA. 1982. U.S. Environmental Protection Agency. Environmental Systems Laboratory. Interim Method for Determination of Asbestos in Bulk Insulation Samples. Research Triangle Park, N.C. EPA 600/M4-82-020.

[2] Asbestos; Friable Asbestos-Containing Materials in Schools; Identification and Notification, Appendix A. Final Rule, Environmental Protection Agency, 40 CFR Part 763, Federal Register Vol. 47, No. 103, 23360, May 27, 1982.

[3] Asbestos; Friable Asbestos-Containing Materials in Schools; Identification and Notification; Correction. 40 CFR Part 763, Federal Register Vol. 47, No. 170,38535, September 1, 1982.

oblique illumination, and a polarizing microscope (100X magnification) equipped with an external illuminator and dispersion staining objective.

Each bulk sample was emptied onto clean weighing paper, and the entire sample was examined as a whole through the stereo microscope for layering, homogeneity, and the presence of fibrous material. Identification of macro-size nonfibrous components was usually possible at this point.

Subsamples of the bulk sample were selected using the stereo microscope. They were then mounted onto a clean microscope slide in the appropriate index of refraction liquids for examination through the polarizing microscope.

The polarized light microscopy procedure consisted of observing the characteristics of the subsample components with transmitted polarized light, crossed polars, slightly uncrossed polars, crossed polars plus the first-order red compensator, and the central stop dispersion staining objective. The observations obtained using the various techniques were used to identify the fibrous and some of the nonfibrous components on the basis of morphology, sign of elongation, and refractive index/dispersion staining colors.

Quantitation of the asbestos was achieved by stereo microscopic observation of the entire bulk sample through the stereo microscope and PLM examination of the subsamples. The volume percentages of the various components were estimated in relationship to the whole sample.

II. DISCUSSION

Table 6-1 lists, by sampling areas, the numbers of samples designated for analysis by MRI, quality assurance analysis by an external laboratory, or storage for a future task. Ninety-two of the samples analyzed were renumbered with a new MRI internal ID number and reanalyzed blind by a second MRI analyst. Table 6-2 gives a comparison of these internal MRI duplicate analyses.

Reanalysis of six samples for asbestos content only was requested by Westat. The samples were coded with a new MRI internal ID number and reanalyzed blind. Table 6-3 compares the results of the original results with the results from the reanalyses.

Environmental Health Laboratories (EHL) of Macon, Georgia, performed the external laboratory analysis. The samples designated for external analysis were logged out of MRI and shipped by express mail to EHL for analysis. The project analytical protocol was provided to EHL to assure uniform analytical methodology. Telephone communiques with EHL were held to discuss the analysis protocol for assurance that it was followed. The externally analyzed samples were returned to MRI and logged back into the task records.

Among the bulk samples analyzed for this report, 39 percent contained asbestos. Of this, chrysotile was found in 92 percent, amosite in 16 percent and crocidolite in 1 percent (3 samples). No other type of asbestos was found. These percentages sum to more than 100 percent because more than one type of asbestos was found in 9 percent of the samples.

Table 6-1. Samples designated for analysis or storage

Sampling area	MRI analysis	External laboratory	Hold[b]
02, 04, 08	268	13	150
06	107	5	58
05	106	3	40
10	43	2	31
09	54	3	37
07	138	7	31
01[a]	182	9	106
03	67	2	44

[a]Includes extra splits prepared by MRI at Westat's direction.

[b]These are primarily vinyl floor tile samples which will be analyzed by PLM upon the development of a suitable analytical protocol. The results will be reported in a separate report.

Table 6-2. Comparison of results of MRI internal QC duplicate analyses

MRI Internal Sample ID No.	Field ID No.	Materials Present: Type and Volume Percent[a]						
		Asbestos		Fibrous Nonasbestos				
		CHR	AMO	GWL	FGL	CEL	OTR	Nonfibrous
7901-17-0365	12799	ND	ND	ND	99	1	T	ND
7901-17-0769QC	12799	ND	ND	ND	99	1	ND	ND
7901-17-0297	92153	ND	ND	ND	ND	ND	1	99
7901-17-0767QC	92153	ND	ND	ND	ND	ND	T	100
7901-17-0359	77336	ND	ND	100	ND	ND	ND	ND
7901-17-0782QC	77336	ND	ND	99	ND	ND	ND	1
7901-17-0287	64740	ND	ND	ND	ND	70	T	30
7901-17-0768QC	64740	ND	ND	ND	ND	80	ND	20
7901-17-0272	30211	98	ND	ND	ND	ND	ND	2
7901-17-0763QC	30211	80	ND	ND	ND	T	ND	20
7901-17-0435	76021	ND	ND	ND	90	ND	ND	10
7901-17-0766QC	76021	ND	ND	ND	95	ND	ND	5
7901-17-0454	87575	ND	ND	ND	96	ND	ND	4
7901-17-0764QC	87575	ND	ND	ND	90	ND	ND	10
7901-17-0361	91809	8	50	ND	ND	ND	ND	42
7901-17-0770QC	91809	15	20	ND	ND	ND	ND	65
7901-17-0378	25459	99	ND	ND	ND	ND	ND	1
7901-17-0771	25459	70	ND	ND	ND	10	ND	20
7901-17-0407	91240	ND	ND	15	ND	70	ND	15
7901-17-0765QC	91240	ND	ND	30	ND	40	ND	30
7901-17-0178	15597	ND	ND	ND	100	T	T	ND
7901-17-0762QC	15597	ND	ND	ND	100	ND	ND	ND
7901-17-0335	01168	ND	ND	57	ND	40	ND	3
7901-17-0772QC	01168	ND	ND	40	ND	40	ND	20
7901-17-0323	68442	ND	ND	ND	ND	ND	1	99
7901-17-0773QC	68442	ND	ND	ND	ND	5	5	90
7901-17-0220	01531	ND	ND	45	ND	45	ND	10
7901-17-0781QC	01531	ND	ND	45	3	30	ND	22
7901-17-0249	29411	ND	ND	ND	ND	99	ND	1
7901-17-0780QC	29411	ND	ND	ND	ND	90	ND	10
7901-17-0268	29590	ND	ND	ND	ND	80	ND	20
7901-17-0778QC	29590	T	ND	ND	ND	80	ND	20
7901-17-0183	59333	ND	1	97	ND	ND	ND	2
7901-17-0777QC	59333	ND	2	83	ND	T	ND	15
7901-17-0169	20530	1	ND	ND	ND	ND	ND	99
7901-17-0779QC	20530	1	ND	ND	ND	T	ND	99
7901-17-0417	04829	ND	ND	ND	ND	95	ND	5
7901-17-0775QC	04829	ND	ND	ND	ND	90	ND	10
7901-17-0466	77096	ND	ND	ND	ND	T	ND	100
7901-17-0776QC	77096	ND	ND	ND	ND	T	ND	100
7901-17-0659	39231	40	ND	ND	ND	60	ND	T
7901-17-0774QC	39231	40	ND	ND	ND	55	ND	5

6-2 (continued)

MRI Internal Sample ID No.	Field ID No.	Materials Present: Type and Volume Percent[a]						
		Asbestos		Fibrous Nonasbestos				
		CHR	AMO	GWL	FGL	CEL	OTR	Nonfibrous
7901-17-0672	57580	ND	ND	ND	ND	98	ND	2
7901-17-0786QC	57580	ND	ND	ND	ND	93	ND	7
7901-17-0682	89152	ND	ND	ND	ND	ND	ND	100
7901-17-0784QC	89152	ND	ND	ND	ND	T	ND	100
7901-17-0697	37690	40	ND	ND	15	ND	ND	45
7901-17-0787QC	37690	5	ND	50	15	ND	ND	30
7901-17-0716	37897	ND	ND	ND	ND	99	ND	1
7901-17-0783QC	37897	ND	ND	ND	ND	90	ND	10
7901-17-0731	57802	20	ND	ND	ND	40	ND	40
7901-17-0788QC	57802	15	ND	15	ND	50	ND	20
7901-17-0747	79844	10	ND	ND	ND	ND	ND	90
7901-17-0789QC	79844	5	ND	ND	T	T	ND	95
7901-17-0761	03652	8	ND	ND	ND	ND	ND	92
7901-17-0785QC	03652	2	ND	ND	T	T	T	98
7901-17-0490	22953	ND	ND	44	ND	45	ND	11
7901-17-1453QC	22953	ND	ND	30	ND	30	ND	40
7901-17-0503	28101	ND	1	20	ND	20	49	10
Reanalysis	28101	T	ND					
7901-17-1452QC	28101	ND	ND	10	ND	65	5	20
Reanalysis QC	28101	ND	T					
Third analyst	28101	ND	1					
7901-17-0517	93983	ND	ND	ND	100	ND	ND	ND
7901-17-1451QC	93983	ND	ND	100	ND	ND	ND	ND
7901-17-0569	20592	ND	ND	80	ND	ND	ND	20
7901-17-1448QC	20592	ND	ND	95	ND	T	ND	5
7901-17-0579	83081	55	ND	30	ND	1	ND	14
7901-17-1450QC	83081	55	ND	25	ND	T	ND	20
7901-17-0591	11254	ND	ND	44	ND	44	ND	12
7901-17-1449QC	11254	ND	ND	30	ND	40	ND	30
7901-17-0616	71312	ND	ND	ND	ND	99	ND	1
7901-17-1184QC	71312	ND	ND	ND	ND	95	ND	5
7901-17-0626	44830	ND	ND	35	ND	47	ND	18
7901-17-1185QC	44830	ND	ND	25	ND	25	ND	50
7901-17-0636	69424	20	ND	ND	ND	ND	ND	80
7901-17-1183QC	69424	5	ND	ND	ND	T	ND	95
7901-17-0646	55823	ND	ND	ND	ND	1	ND	99
7901-17-1187QC	55823	ND	ND	ND	ND	T	1	99
7901-17-0054	96869	93	ND	ND	ND	1	ND	6
7901-17-1186QC	96869	70	ND	ND	T	5	ND	25
7901-17-0811	80247	90	ND	ND	ND	ND	ND	10
7901-17-1179QC	80247	60	ND	ND	ND	ND	ND	40
7901-17-0824	16115	ND	ND	39	ND	55	ND	6
7901-17-1178QC	16115	ND	ND	30	ND	30	ND	40
7901-17-0843	77897	ND	ND	30	ND	59	ND	11
7901-17-1188QC	77897	ND	ND	25	ND	25	ND	50

6-2 (continued)

MRI Internal Sample ID No.	Field ID No.	Materials Present: Type and Volume Percent[a] Asbestos CHR	AMO	Fibrous Nonasbestos GWL	FGL	CEL	OTR	Nonfibrous
7901-17-1145	78620	ND	ND	59	ND	39	ND	2
7901-17-1174QC	78620	ND	ND	64	ND	30	ND	6
7901-17-1146	97974	ND	ND	50	ND	49	ND	1
7901-17-1613QC	97974	ND	ND	30	ND	60	ND	10
7901-17-1155	81564	ND	ND	99	ND	ND	ND	1
7901-17-1175QC	81564	ND	ND	99	ND	ND	ND	1
7901-17-1165	57016	ND	ND	98	ND	ND	ND	2
7901-17-1176QC	57016	ND	ND	94	ND	T	T	6
7901-17-0848	79661	ND	ND	ND	100	ND	ND	T
7901-17-1180QC	79661	ND	ND	ND	90	ND	ND	10
7901-17-0861	55660	3	ND	ND	ND	ND	ND	97
7901-17-1182QC	55660	5	ND	ND	ND	1	ND	94
7901-17-0882	75751	ND	ND	ND	ND	93	ND	7
7901-17-1177QC	75751	ND	ND	ND	ND	90	ND	10
7901-17-0898	18915	T	ND	ND	ND	T	ND	100
7901-17-1181QC	18915	ND	ND	ND	ND	T	ND	100
7901-17-0924	81566	ND	ND	65	ND	T	ND	35
7901-17-1192QC	81566	ND	ND	50	ND	T	ND	50
7901-17-0939	46155	T	ND	ND	ND	95	ND	5
7901-17-1190QC	46155	ND	ND	ND	ND	95	ND	5
7901-17-0953	64942	1	ND	ND	ND	ND	ND	99
7901-17-1191QC	64942	T	ND	ND	ND	1	ND	99
7901-17-0968	56919	ND	ND	ND	ND	ND	ND	100
7901-17-1575QC	56919	ND	ND	ND	ND	T	ND	100
7901-17-0982	06591	ND	ND	42	ND	43	ND	15
7901-17-1571QC	06591	ND	ND	50	ND	25	ND	25
7901-17-0990	97723	ND	ND	ND	ND	T	ND	100
7901-17-1570QC	97723	ND	ND	ND	ND	ND	ND	100
7901-17-1002	93727	ND	ND	ND	ND	ND	ND	100
7901-17-1573QC	93727	ND	ND	ND	ND	ND	ND	100
7901-17-1012	92061	ND	ND	65	ND	30	ND	5
7901-17-1572QC	92061	ND	ND	60	ND	30	ND	10
7901-17-0944	86199	ND	ND	ND	ND	97	ND	3
7901-17-1189	86199	ND	ND	ND	ND	95	ND	5
7901-17-1107	70071	ND	ND	ND	ND	ND	ND	100
7901-17-1582QC	70071	ND	ND	ND	ND	ND	ND	100
7901-17-1027	68839	ND	ND	ND	85	ND	ND	15
7901-17-1569QC	68839	ND	ND	9	80	ND	ND	11
7901-17-1040	34935	30	ND	ND	50	ND	ND	20
7901-17-1574QC	34935	30	1	30	20	ND	ND	20
7901-17-1054	05346	8	ND	ND	ND	2	ND	90
7901-17-1576QC	05346	T	ND	ND	ND	1	ND	99
7901-17-1065	17655	95	ND	ND	ND	ND	ND	5
7901-17-1579QC	17655	70	ND	T	ND	20	ND	10
7901-17-1076	85020	15	ND	ND	ND	ND	ND	85
7901-17-1580QC	85020	2	ND	ND	ND	3	ND	95

6-2 (continued)

MRI Internal Sample ID No.	Field ID No.	Materials Present: Type and Volume Percent[a] Asbestos CHR	AMO	Fibrous Nonasbestos GWL	FGL	CEL	OTR	Nonfibrous
7901-17-1089	43415	ND	ND	46	ND	46	ND	8
7901-17-1577QC	43415	ND	ND	50	ND	40	ND	10
7901-17-1115	87384	ND	2	96	ND	T	ND	2
7901-17-1581QC	87384	ND	5	90	ND	ND	ND	5
7901-17-1125	86351	85	ND	ND	ND	ND	ND	15
7901-17-1583QC	86351	75	ND	ND	ND	1	ND	24
7901-17-1200	44896	40	2	ND	40	ND	ND	18
7901-17-1602QC	44896	2	25	ND	50	ND	ND	23
7901-17-1216	69761	ND	ND	50	ND	ND	ND	50
7901-17-1603QC	69761	ND	ND	ND	10	ND	ND	90
7901-17-1229	84664	1	ND	ND	ND	ND	ND	99
Reanalysis	84664	ND						
7901-17-1601QC	84664	ND	ND	ND	ND	1	ND	99
7901-17-1246	09165	90	ND	1	ND	ND	ND	9
7901-17-1599QC	09165	60	ND	ND	5	20	ND	15
7901-17-1257	43676	ND	ND	20	ND	10	ND	70
7901-17-1595QC	43676	ND	ND	ND	20	20	ND	60
7901-17-1271	15889	ND	60	ND	ND	ND	ND	40
7901-17-1598QC	15889	ND	80	ND	ND	ND	ND	20
7901-17-1282	39890	ND	ND	ND	ND	100	ND	ND
7901-17-1600QC	39890	ND	ND	ND	ND	90	ND	10
7901-17-1292	24488	ND	ND	ND	ND	99	ND	1
7901-17-1591QC	24488	ND	ND	ND	ND	100	ND	ND
7901-17-1307	13175	ND	ND	ND	100	ND	ND	ND
7901-17-1597QC	13175	ND	ND	ND	100	ND	ND	ND
7901-17-1318	89886	2	ND	ND	ND	ND	ND	98
7901-17-1590QC	89886	5	ND	ND	ND	ND	ND	95
7901-17-1329	00471	ND	30	65	ND	ND	ND	5
7901-17-1596QC	00471	ND	75	25	T	ND	ND	ND
7901-17-1340	19606	1	ND	25	ND	ND	ND	74
7901-17-1593QC	19606	2	ND	38	ND	ND	T	60
7901-17-1340	19606	1	ND	25	ND	ND	ND	74
7901-17-1593QC	19606	2	ND	38	ND	ND	T	60
7901-17-1355	42942	ND	ND	41	ND	45	ND	14
7901-17-1594QC	42942	ND	ND	40	ND	30	ND	30
7901-17-1392	80516	ND	ND	ND	ND	97	ND	3
7901-17-1592QC	80516	ND	ND	ND	ND	100	ND	T
7901-17-1456	69401	ND	ND	ND	96	ND	ND	4
7901-17-1610QC	69401	ND	ND	ND	99	ND	ND	1
7901-17-1466	26236	ND	ND	ND	ND	80	ND	20
7901-17-1605QC	26236	ND	ND	T	ND	50	ND	50
7901-17-1477	80060	ND	ND	ND	90	5	ND	5
7901-17-1609QC	80060	ND	ND	ND	90	5	ND	5
7901-17-1488	98924	30	ND	ND	ND	ND	ND	70
7901-17-1606QC	98924	1	ND	ND	ND	5	T	94

6-2 (concluded)

MRI Internal Sample ID No.	Field ID No.	Materials Present: Type and Volume Percent[a] Asbestos CHR	AMO	Fibrous Nonasbestos GWL	FGL	CEL	OTR	Nonfibrous
7901-17-1513	25873	25	ND	ND	ND	ND	ND	75
7901-17-1607QC	25873	1	ND	ND	ND	4	ND	95
7901-17-1536	49375	ND	ND	ND	ND	90	ND	10
7901-17-1604QC	49375	ND	ND	ND	ND	90	ND	10
7901-17-1554	39881	ND	ND	44	ND	50	ND	6
7901-17-1608QC	39881	ND	ND	60	ND	35	ND	5
7901-17-1206	25947	ND	T	94	ND	T	ND	6
7901-17-1611QC	25947	ND	1	89	ND	ND	ND	10
7901-17-1094	09383	10	ND	ND	ND	ND	ND	90
7901-17-1578QC	09383	2	ND	ND	ND	8	ND	90

a CHR = chrysotile; AMO = amosite; GWL = glass wool or mineral wool; FGL = fiberglass; CEL = cellulose; OTR = other fibrous materials (e.g., synthetics); ND = not detected; and T = trace amount, < 1%.

Table 6-3. Results from six samples reanalyzed at Westat's request

Field ID No.	Original Analysis	Reanalysis
89152	Not detected	Not detected
64942	1% Chrysotile	1% Chrysotile
81909	Not detected	1% Chrysotile
77719	Not detected	1% Chrysotile
48651	Trace Chrysotile	Not detected
90564	Not detected	Not detected

The range of percent asbestos content found was 1 percent to 70 percent amosite in 64 samples, 1 percent to 100 percent chrysotile in 358 samples, and 5 percent to 20 percent crocidolite in 3 samples. The distributions of percent asbestos are shown in Table 6-4 for both amosite and chrysotile asbestos.

Table 6-4. Distribution of percent asbestos content in samples where amosite and chrysotile asbestos was found

Percent Amosite	Percent of samples	Percent Chrysotile	Percent of samples
1-10%	41%	1-10%	25%
11-20	11	11-20	7
21-30	6	21-30	12
31-40	17	31-40	7
41-50	11	41-50	8
51-60	12	51-60	3
61-70	2	61-70	4
71-80	0	71-80	4
81-90	0	81-90	15
91-100	0	91-100	15
	(64 samples)		(358 samples)

SECTION 7

STATISTICAL ANALYSIS AND RESULTS

In this section we present detailed tables and discussion of results. We begin by describing the calculation of final weights and variances, and then proceed to the findings. The final weights were used to estimate national totals from the sampled buildings. Because the sample was not self-weighting, the correct calculation of weights was crucial to the final results. A summary of the major results appear as Section 2, and the results are also given in brief in the Executive Summary.

I. ESTIMATION AND VARIANCE CALCULATIONS

The plan for calculating final weights and variances is given as Appendix F. We briefly review the calculations here. In order to make national estimates for 3.6 million buildings based on a sample of 231 buildings, the results for each sampled building must be multiplied by a number known as the weight, which is the number of buildings nationwide represented by the sampled building. These weighting factors are based on the building's probability of selection -- for example if one building in a hundred were sampled, then the building base weight would be one hundred. These base weights are modified, or adjusted, to reflect differences between the initial sample and the final sample, and to reflect outside knowledge.

The initial base weights are merely the inverse of the probability of selection. This probability is based on the site (PSU), type of building, and size class of the sample building.

A further component is reflected in the weights of buildings subsampled from a sampled complex (i.e., group of buildings). The first modification occurs at the building level, for buildings which had multiple addresses, and therefore a multiple chance of selection from the address list. The building probabilities were adjusted appropriately.

The remaining adjustments were done by size class for each type of building. Adjustments to the base weights were made to reflect the substitutions done for ineligible buildings. These adjustments reduced the weights so that the weighted totals would reflect the number of eligible buildings on the frame rather than the total number of buildings on the frame. No adjustment was needed for substitutions made for eligible buildings which were not inspected. However, in a few instances, there were not enough eligible buildings to provide substitutes for all noncooperating buildings. In those cases, the building weights were increased to reflect the loss of eligible buildings from the final set of inspected buildings.

The final set of adjustments involved adjusting building weights, again by type of building and size class, using information known from outside the study. We did not have an outside source for the actual number of buildings which would fall in our study definition for Federal government buildings, so Federal government adjustments occurred at the frame level. Primary Sampling Unit (PSU) weights were adjusted to bring weighted PSU totals in line with the frame totals for the continental U.S.

For residential buildings with 10 or more rental units we also did not have an external data source for number of buildings. However, we did adjust the PSU weights so that weighted PSU totals would reflect the stratum (region by PSU size) totals for the number of dwelling units in 10 or more unit buildings.

For private nonresidential buildings, an outside data source is available, the 1981 Department of Energy (DOE) Survey of Energy Consumption in Nonresidential Buildings. From the data tape produced for that survey, buildings which met the study definition of private nonresidential were selected and national estimates based on these buildings were created for each size class. Thus for this segment of the building population, the total number of buildings in the target universe was known fairly precisely, and the building weights were adjusted to sum to that total.

The final weights were attached to the clean data file and used in the calculation of national estimates. Sampling variances for these estimates were estimated using the method of balanced repeated replication, implemented by a procedure in the computer system SAS. The method is described in more detail in Appendix F. In this method, PSUs are paired, and a series of replicates is defined, consisting of two half-samples with one PSU from each pair in each half-sample. For each replicate, two national estimates are made, one from each half-sample. Thus separate weights must be calculated for each replicate, incorporating all adjustments. Each replicate then contributes one squared difference to the overall estimated variance. This method allows the inclusion in the variance estimates of the effects of adjustments made to the weights.

See Section 5, Part III, for a discussion of the definitions used in the study, especially the target universe, and descriptions of nonsampling and sampling errors in the estimates.

II. RESULTS BY BUILDING TYPE

This part of the report presents results relating to the major study objective by the three sampling strata of building types: Federal government, residential, and private non-residential. The results are presented in tabular form and discussed in the accompanying text. Tables containing number of buildings are rounded to thousands and square footage is given in millions. Due to this and internal rounding of weights in SAS, the totals are not always exactly equal to the sum of the cell entries.

A. Number of Buildings

Table 7-1 gives the number of inspected buildings for each type of building, the estimated universe totals for each type, with 95 percent confidence limits, and the percent of the universe represented by each building type. We estimate that 3,606,000 buildings fall into one of our three categories nationally (for full definition of the building types, see Section 4, Part IA). In the set of inspected buildings, about one-quarter are Federal government, about one-quarter are residential, and half are private nonresidential. This allocation was deliberate in order to have enough buildings of each type to make separate estimates by type with desired precision. However, the breakdown of the total population of buildings is quite different with private nonresidential buildings accounting for nearly 90 percent of the total. Thus our estimates for all buildings combined will reflect this type most heavily.

Tables 7-2 and 7-3 show the estimated number and percent of buildings in the target universe with asbestos-containing material. Very few buildings have asbestos-containing ceiling

Table 7-1. Sample size and estimated universe number of buildings by building type (95 percent confidence limits in parentheses)

Building type	Sample size	Estimated universe total (in 1,000s)	Estimated percent of total universe
Federal government	66	35 (20-49)	1%
Residential (10+ rental units)	55	350 (269-432)	10%
Private nonresidential (commercial)	110	3221 (a)	89%
Private total	165	3571 (3490-3653)	99%
All buildings	231	3606 (3533-3680)	100%

[a] The private nonresidential universe size was known from other sources (DOE, 1981) and did not have to be estimated from survey data.

Table 7-2. Estimated number of buildings with asbestos-containing material[a] by type of material and type of building (in 1,000s) (95 percent confidence limits in parentheses)

Building type	Asbestos-containing material: Sprayed- or trowelled-on friable[b]	Ceiling tile	Pipe/ boiler insulation	Any[c]
Federal government	5 (<10)	1 (< 2)	9 (<18)	14 (8-20)
Residential (10+ rental units)	64 (34-94)	2 (<6)	155 (66-243)	208 (119-297)
Private non-residential (commercial)	122 (< 275)	0[d]	400 (76-724)	511 (274-748)
Private total	186 (15-357)	2 (< 6)	555 (234-876)	719 (489-949)
All buildings[e]	192 (18-365)	2 (< 6)	563 (239-888)	733 (499-966)

[a]One percent or more asbestos found in laboratory analysis.

[b]Includes friable material applied to surfaces and steel beams.

[c]Will not be the sum of the columns.

[d]Of 110 inspected private nonresidential buildings none had asbestos-containing ceiling tile. However, some small number of buildings in this category may have asbestos-containing ceiling tile.

[e]May not equal sum of rows due to rounding.

Table 7-3. Estimated percent[a] of buildings with asbestos-containing material[b] by type of material and building type

(95 percent confidence limits in parentheses)

Building type	Asbestos-containing material			
	Sprayed- or trowelled-on friable[c]	Ceiling tile	Pipe/ boiler insulation	Any[d]
Federal government	16 (133)	2 (14)	25 (8-41)	39 (29-48)
Residential (10+ rental units)	18 (10-27)	0[e] (12)	44 (26-62)	59 (45-74)
Private non-residential (commercial)	4 (19)	0[f]	12 (2-22)	16 (9-23)
Private total	5 (110)	0[e] (11)	16 (6-25)	20 (14-27)
All buildings	5 (1-10)	0[e] (11)	16 (7-25)	20 (14-27)

[a]May not equal percentages calculated directly from Tables 7-1 and 7-2 due to rounding in those tables and in this one.

[b]One percent or more asbestos found in laboratory analysis.

[c]Includes friable material applied to surfaces and steel beams.

[d]Will not be the sum of the columns.

[e]Less than 0.5 percent.

[f]Of 110 inspected buildings of this type, none had asbestos-containing ceiling tile. However, some small number of buildings in this category may have abestos-containing ceiling tile.

tile, although many of the inspected buildings contained ceiling tile. Only one-tenth of one percent of all buildings with ceiling tile have asbestos-containing ceiling tile (this statistic is not shown in the table). For the other types of material, 5 percent of all buildings have asbestos-containing sprayed- or trowelled-on friable material, 16 percent have asbestos-containing pipe or boiler insulation, and 20 percent of buildings have any asbestos-containing material.

In comparing the types of buildings, the highest percent of buildings with asbestos-containing materials is residential, followed closely by Federal government, with much lower percentages in private nonresidential buildings. Because private nonresidential buildings form the bulk of the total, there are more such buildings with asbestos-containing materials, but the percentage of buildings is much lower. These results hold for all types of material except ceiling tile.

B. Building Square Footage

In addition to figures on numbers of buildings with asbestos-containing friable material, the survey provided estimates of total square footage for all buildings and buildings with asbestos-containing materials. The primary interest of these numbers is to provide a background for data on square footage of material. In addition, comparing the estimates of numbers of buildings with estimates of building square footage gives an indication of whether the buildings with asbestos tend to be large, small, or about average in size.

Table 7-4 shows two sets of statistics. The first two columns indicate the breakout of the target universe by building square footage. With an estimated 699 million square feet of

Table 7-4. Estimated building square footage for all buildings and buildings with asbestos-containing[a] sprayed- or trowelled-on friable material (in 1,000,000's)

Building type	Estimated total building square footage of all buildings	Estimated percent of target universe total square footage	Estimated total building square footage of buildings with asbestos-containing sprayed- or trowelled-on friable material[b]
Federal government	699	2%	210
Residential (10+ rental units)	7,692	19%	1,063
Private nonresidential	31,573	79%	4,383
Privately owned building total[c]	39,264	98%	5,446
All buildings[c]	39,963	100%	5,656

[a] One percent or more asbestos found in laboratory analysis.

[b] Includes material on surfaces and steel beams.

[c] May not equal sum of rows due to rounding.

building, Federal government buildings account for two percent of total building square footage, while this category includes one percent of all buildings (see Table 7-1). Further, the residential buildings' 7.7 billion square feet represent 19 percent of estimated total building square footage, while the number of residential buildings, 350 thousand, represents only 10 percent of the estimated total number of buildings. From these comparisons we infer that Federal government and residential buildings with ten or more rental units tend to be larger on average than private nonresidential buildings (although no test of statistical significance has been done).

Table 7-4 also allows us to consider the percentage of building square footage represented by buildings with asbestos-containing sprayed- or trowelled-on friable material, and then compare this with the percent of all buildings with such material, by building type. These comparisons have not been tested for statistical significance, but can be considered as interesting indications in the data. We saw in Table 7-3 that an estimated 5 percent of all buildings have asbestos-containing sprayed- or trowelled-on friable material. From Table 7-4 we find that these buildings account for 5.6 billion square feet of the 40 billion square feet in all buildings, or 14 percent of building square footage. This indicates that the buildings with asbestos-containing sprayed- or trowelled-on friable material tend to be larger on average than all buildings. Similar statements hold for all building types except rental residential, where 18 percent of buildings have asbestos-containing sprayed- or trowelled-on friable material, representing 14 percent of building square footage in that category.

C. Square Footage of Asbestos-Containing Friable Materials

The second major objective of the survey was to estimate the amount of asbestos-containing friable material in buildings. Table 7-5 gives the national estimates for sprayed- and trowelled-on friable material and Table 7-6 gives estimates for ceiling tile. Both tables give the estimated square footage of material, the estimated square footage of asbestos-containing material, and the percent of all material which contains asbestos.

Thus, in Table 7-5, we estimate that buildings in our target universe contain a total of 4.7 billion square feet of sprayed- or trowelled-on friable material, of which 1.2 billion square feet, or one-quarter of the material, contains asbestos. The breakdown by building type shows that for Federal government buildings an estimated two-thirds of the material contains asbestos. The remaining building types are close to the one-quarter figure.

Looking at Tables 7-4 and 7-5 together, we find that the estimated sprayed- or trowelled-on material square footage for residential buildings is one-quarter the estimated building square footage, while for private nonresidential buildings the estimated sprayed- or trowelled-on material square footage is less than one-tenth of the building square footage. This implies that residential rental buildings are more likely to have sprayed- or trowelled-on friable material (often in the form of acoustic or decorative ceiling plaster) than private nonresidential buildings, although if present the material is equally likely to contain asbestos in either type of building.

Table 7-6 repeats the exercise for ceiling tile. Overall, less than one-half of one percent of ceiling tile found (by square footage) contained asbestos. This is out of an estimated

Table 7-5. Square footage of sprayed-or trowelled-on material, all material and asbestos-containing[a], by building type (in 1,000,000's). Percent of such material which contains asbestos.

Building type	Square footage of sprayed- or trowelled-on friable material	Square footage of asbestos-containing sprayed- or trowelled-on friable material	Percent of material which contains asbestos
Federal government	106	71	67%
Residential (10+ rental units)	1,984	537	27%
Private nonresidential	2,598	576	22%
Private total	4,582	1,113	24%
All buildings	4,688	1,184	25%

[a]One percent or more asbestos found in laboratory analysis.

Table 7-6. Square footage of ceiling tile and asbestos-containing[a] ceiling tile by type of building (in 1,000,000's). Percent of ceiling tile which contains asbestos.

Building type	Square footage of ceiling tile	Square footage of asbestos-containing ceiling tile	Percent of ceiling tile which contains asbestos
Federal government	307	2	1%
Residential (10+ rental units)	107	2	1%
Private nonresidential	9,498	0 [b]	0%[b]
Private total[c]	9,606	2	0%[d]
All buildings[c]	9,913	4	0%[d]

[a]One percent or more asbestos found in laboratory analysis.

[b]Of 110 private nonresidential buildings inspected, none had asbestos-containing ceiling tile. However, some small amount of such material may exist in buildings in this category.

[c]May not equal sum of rows due to rounding.

[d]Less than 0.5 percent.

nearly 10 billion square feet of ceiling tile in the target universe buildings, over twice as much square footage as estimated in Table 7-5 for sprayed- and trowelled-on friable material. Although some ceiling tile does contain asbestos, and in specific cases can contribute to a serious exposure problem, at the national level the scale of asbestos in ceiling tile is much lower than asbestos in sprayed- or trowelled-on material.

D. Percent Asbestos in Materials

Results for the third major objective of the study, the percent of asbestos found in asbestos-containing materials, are shown in Table 7-7. Asbestos-containing ceiling tile averages only 2 to 3 percent asbestos content. Thus not only did we rarely find asbestos in ceiling tile; when we did, there was not very much asbestos present.

The sprayed- and trowelled-on friable materials showed an average of 14 percent asbestos, ranging from 9 percent among residential buildings (presumably in the largely decorative ceiling plaster type of material) to 29 percent in Federal government buildings. Fluffy sprayed-on type of insulation was also found more often in Federal government buildings.

The asbestos-containing pipe and boiler insulation, not surprisingly, contained the most asbestos, an average of about 70 percent. This finding reflects the bulk sampling protocol for pipe wrap--to sample at damaged or exposed places which may have higher percent asbestos content than areas not sampled. In this column, Federal buildings have lower asbestos content insulation, about 55 percent asbestos, residential buildings fall in the middle with 67 percent and private nonresidential buildings

Table 7-7. Percent asbestos found[a] in bulk samples of asbestos-containing[b] materials by material type and building type (95 percent confidence limits in parentheses)

Building type	Asbestos-containing sprayed- or trowelled-on friable material[c]	Asbestos-containing ceiling tile	Asbestos-containing pipe/boiler insulation material[d]
Federal government	29.3 (22.6-36.0)	3.4 (< 10.7)	54.7 (46.0-63.4)
Residential (10+ rental units)	9.0 (1.0-17.1)	2.0 (< 5.2)	67.3 (55.6-78.9)
Private nonresidential	16.6 (0.3-32.9)	--[e]	71.1 (61.9-80.3)
Private total	13.0 (6.6-19.4)	2.0 (< 4.8)	70.0 (66.1-73.9)
All buildings	13.9 (7.1-20.8)	2.8 (< 8.5)	69.8 (65.8-73.8)

[a]Average percent weighted by square footage of material when appropriate.

[b]One or more percent asbestos found in laboratory analysis.

[c]Includes material on surfaces and steel beams.

[d]Sampled damaged or exposed material.

[e]Since no inspected buildings of this type had asbestos-containing ceiling tile, no estimate could be made of percent asbestos in ceiling tile for this type of building.

had the most with 71 percent asbestos. However, the confidence limits indicate that the only one of these types of buildings that may be significantly different from the average is the Federal government type.

E. Exposed Asbestos-Containing Materials by Building Type

One characteristic of the materials which was collected as a data item for sprayed- or trowelled-on friable material and for ceiling tile was whether the material was directly exposed to the public areas or whether it was hidden, for example, behind drop ceilings or inside walls or crawl spaces. In our sample of buildings and in our national estimates as well, we found very little material that was not exposed, and the characteristics of the exposed material did not appear to differ from all material. Prior to conducting the study, it was hypothesized that friable material sprayed on steel beams, concealed behind drop ceilings, would be found often and would constitute the bulk of asbestos-containing friable material. This was not the experience of the survey. Steel-beam buildings with sprayed-on friable material were inspected and contribute their part to the national estimates. However, nationally such buildings appear to represent only a small proportion of the target universe building stock. Further, we found that in the sampled buildings which were of steel-beam construction with sprayed-on material, the material did not always contain asbestos.

III. OTHER BUILDING CHARACTERISTICS

Since the sample was drawn by building type, we presented those findings first. However, other building characteristics were also recorded. In the remainder of this Section we examine those characteristics and their association with asbestos. Here we look at the observed distributions of the characteristics. The three building characteristics recorded were construction date, height (number of floors) and construction type. In our sample, we did not get enough variety of construction types for valid estimates to be made for each type, so we do not report results by construction type here. In tables by building height we show buildings with one or two floors and buildings with three or more floors. Our sample of buildings, as drawn, does not allow us to offer separate statistics on tall buildings (15 or more floors).

We begin by comparing our survey estimates of the percent distribution by construction date and building height with those from the Department of Energy Nonresidential Building Energy Consumption Survey, 1981*. That survey consisted of interviews and observations on 6,000 buildings nationally and is the only source of survey data available on the U.S. building stock. The survey defined as nonresidential all buildings with any commercial activity, so that many apartment buildings are included (for example, an apartment building with office space on the lower floors, or with a beauty salon or other business serving the tenants would be included in the DOE survey.) So the target universe of the Asbestos in Buildings Survey is fairly comparable to that of the DOE survey. In Tables 7-8 and 7-9 we see that our 95 percent confidence limits on percent distribution by construction date and height include the DOE estimates. Thus, our survey is in agreement with the DOE survey: buildings are approximately evenly distributed across the four defined time spans, and a large majority of buildings are only one or two stories tall.

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*U.S. Department of Energy, 1981. Nonresidential Buildings Energy Consumption Survey: Building Characteristics. DOE/EIA - 0246.

Table 7-8. Sample size, survey estimate of number and percent distribution of buildings by construction date, DOE survey[a] estimate of percent distribution. Asbestos in Buildings survey estimates show 95 percent confidence limits in parentheses.

Construction date	Sample size	Survey estimate		DOE estimated percent of buildings	
		Number of buildings (in 1,000s)	Percent of total	Years	Percent
Up to 1944	69	924 (350-1,498)	26% (10-42%)	Up to 1945	37%
1945-1959	49	1,051 (380-1,722)	29% (11-48%)	1946-1960	25%
1960-1969	66	797 (385-1,210)	22% (11-34%)	1961-1970	18%
1970-1978	47	834 (474-1,194)	23% (13-33%)	1971-1978	19%
All buildings	231	3,606 (3,533-3,680)	100%	All	100%

[a] Department of Energy, Nonresidential Building Energy Consumption Survey, 1981.

Table 7-9. Sample size, survey estimate of number and percent distribution of buildings by height, DOE survey[a] estimate of percent distribution. Asbestos in Buildings survey estimates show 95 percent confidence limits in parentheses.

Building height	Sample size	Survey estimate		DOE estimated percent of buildings
		Number of buildings (in 1,000s)	Percent of total	
1-2 floors	151	3,080 (2,750-3,411)	85% (76-95%)	80%
3 or more floors	80	526 (205-846)	15% (6-23%)	20%
Total	231	3,606 (3,533-3,680)	100%	100%

[a]Department of Energy, Nonresidential Buildings Energy Consumption Survey, 1981.

In Table 7-10 we look at building height by type of building. The rental residential (10 or more units) category shows an opposite pattern to all other types of buildings -- the majority (65 percent) have three or more floors. This is no doubt due to our restriction of this category to buildings with ten or more units. Most such buildings will consist of either three floors of apartments or two floors of apartments with a basement, which was defined as three floors for this study.

Table 7-11 gives the estimated number of buildings by construction date and type of building. No significant differences appear among the building types, although Federal buildings appear to be slightly older than all buildings.

IV. PRESENCE OF ASBESTOS BY CONSTRUCTION DATE

In this section we look at the basic survey estimates by construction date. Recalling Table 7-8, we found that buildings are fairly evenly distributed among World War II (WWII) and before, post-WWII, the 1960's and the 1970's. (Buildings built after 1978 were not surveyed.) Tables 7-12 and 7-13 show the number and percent of buildings with asbestos-containing material for each age category. We see a great concentration of asbestos-containing sprayed- or trowelled-on friable materials in the sixties -- 15 percent of buildings built then have it, compared to two and one percent of buildings in the earlier periods. Looked at another way, 84 percent of buildings with asbestos-containing sprayed- or trowelled-on friable materials were built in 1960-78, although only 45 percent of all buildings were built in that period.

Table 7-10. Estimated number of buildings (in 1,000's) by building type and height (sample size in parentheses)

Building type	Building height		
	1-2 floors	3 or more floors	All buildings [a]
Federal government	28 (40)	7 (26)	35 (66)
Residential (10+ rental units)	122 (20)	229 (35)	350 (55)
Private nonresidential	2,931 (91)	290 (19)	3,221 (110)
All buildings [a]	3,080 (151)	526 (80)	3,606 (231)

[a] May not equal total of cells due to rounding.

Table 7-11. Estimated number of buildings (in 1,000's) by construction date and type of building (sample size in parentheses)

Construction date	Type of building: Federal government	Residential (10+ rental units)	Private non-residential	Total[a]
Up to 1944	11 (23)	48 (11)	865 (35)	924 (69)
1945 - 59	5 (11)	96 (11)	949 (27)	1,051 (49)
1960 - 69	13 (18)	119 (20)	666 (28)	797 (66)
1970 - 78	5 (14)	88 (13)	741 (20)	834 (47)
Total[a]	35 (66)	350 (55)	3,221 (110)	3,606 (231)

[a]May not equal sum of cell entries due to rounding of weights in calculating cells and totals.

Table 7-12. Estimated number of buildings with asbestos-containing materials[a] by type of material and construction date (in 1,000's) (95 percent confidence limits in parentheses)

Construction date	Asbestos-containing material			
	Sprayed- or trowelled-on friable[b]	Ceiling tile	Pipe/ boiler insulation	Any[c]
Up to 1944	18 (< 45)	0[d]	340	355 (45-665)
1945 - 1959	13 (< 37)	0[d]	142	146 (7-284)
1960 - 1969	122 (<295)	2	81	192 (41-344)
1970 - 1978	39 (22-56)	0[e]	2	39 (23-56)
All buildings[f]	192 (18-365)	2 (< 6)	563 (239-888)	733 (499-966)

[a]One percent or more asbestos found in laboratory analysis.

[b]Includes friable material applied to surfaces and steel beams.

[c]Will not be the sum of the columns.

[d]Less than 500.

[e]Of 47 inspected buildings built in 1970-1978, none had asbestos-containing ceiling tile. However, some small number of buildings in this category may have asbestos-containing ceiling tile.

[f]May not equal sum of rows due to rounding.

Table 7-13. Estimated percent of buildings with asbestos-containing materials[a] by type of material and construction date

Construction date	Asbestos-containing material			
	Sprayed- or trowelled-on friable[b]	Ceiling tile	Pipe/ boiler insulation	Any[c]
Up to 1944	2	0[d]	37	38
1945 - 1959	1	0[d]	13	14
1960 - 1969	15	0[d]	10	24
1970 - 1978	5	0[e]	0[d]	5
All buildings	5	0[d]	16	20

[a]One percent or more asbestos found in laboratory analysis.

[b]Includes friable material applied to surfaces and steel beams.

[c]Will not be the sum of the columns.

[d]Less than 0.5 percent.

[e]Of the 47 inspected buildings built in 1970-1978, none had asbestos-containing ceiling tile. However, some small number of buildings in this category may have asbestos-containing ceiling tile.

We also see a definite trend towards fewer buildings with asbestos-containing pipe and boiler insulation as buildings become more recent. In conclusion, more of the newer buildings have asbestos-containing sprayed- or trowelled-on friable material and more of the older buildings have asbestos-containing pipe and boiler insulation.

In Table 7-14 we look at the square footage of asbestos-containing sprayed- or trowelled-on friable material by date, and what percent of all such material this represents. The majority of asbestos-containing sprayed- or trowelled-on friable material (56 percent of the square footage or 666 million out of 1,184 million square feet) is found in buildings built in the sixties. This is partially due to increased use of sprayed- or trowelled-on friable materials then, especially the difference between 1945-59 and 1960-69. However, for WWII and before, we see that only two percent of all sprayed- or trowelled-on friable material contained asbestos. In the pre-1945 period, there was extensive use of nonasbestos-containing sprayed- or trowelled-on friable material.

Finally, in Table 7-15 we see the asbestos content of various asbestos-containing materials by building age. The sprayed- or trowelled-on friable material used from 1945-1969 appears to have slightly higher asbestos content (15-20 percent) than that used before and after those dates (less than 10 percent). However, the uncertainty due to variance in samples analyzed and precision of the percent asbestos finding in a given sample means that this should be viewed as an interesting note rather than a firm finding. The main finding in this table is that the pattern of asbestos content seen in all buildings is fairly similar across building construction dates.

Table 7-14. Square footage of sprayed- or trowelled-on material, all material and asbestos-containing[a], by construction date (in 1,000,000's). Percent of such material which contains asbestos.

Construction date	Square footage of sprayed- or trowelled-on friable material	Square footage of asbestos-containing sprayed- or trowelled-on friable material	Percent of material which contains asbestos
Up to 1944	1,958	38	2%
1945 - 1959	275	118	43%
1960 - 1969	1,460	666	46%
1970 - 1978	995	362	36%
All buildings	4,688	1,184	25%

[a]One or more percent asbestos found in laboratory analysis.

Table 7-15. Estimated average percent asbestos in asbestos-containing[a] materials by type of material and construction date

Construction date	Asbestos-containing material: Sprayed or trowelled on friable material[b]	Ceiling tile	Pipe/boiler insulation[c]
Up to 1944	6% (<16%)	1%	69%
1945 - 1959	18% (<48%)	8%	70%
1960 - 1969	17% (<34%)	2%	71%
1970 - 1978	9% (7-10%)	--[d]	59%
All buildings	14% (7-21%)	3%	70%

[a]One or more percent asbestos found in laboratory analysis.

[b]Includes material sprayed on surfaces and steel beams.

[c]Sampled damaged or exposed material.

[d]Of 47 inspected buildings built in 1970-1978, none had asbestos-containing ceiling tile. Thus the percent asbestos in asbestos-containing ceiling tile could not be estimated.

V. PRESENCE OF ASBESTOS BY BUILDING HEIGHT

In Table 7-9 we saw that an estimated eighty-five percent of buildings in our target universe have one or two floors. In Table 7-16, however, we estimate that the majority of buildings with any asbestos-containing material (52 percent or 380,000 out of 733,000 buildings) are three or more stories tall. This is due to asbestos-containing pipe and boiler insulation. The sprayed- or trowelled-on friable material column shows that the distribution of buildings with asbestos-containing sprayed- or trowelled-on friable materials by height was the same as the overall distribution by height. This means that buildings with one to two floors are as likely as those with three or more floors to have asbestos-containing sprayed- or trowelled-on friable material, as shown in Table 7-17. Looking at the square footage of sprayed- or trowelled-on friable materials in Table 7-18, we see that the bulk of such material with asbestos (72 percent or 859 million out of 1,184 million square feet) is found in one or two story buildings, and that such material in short buildings is more likely to contain asbestos than in taller buildings (54 percent of material vs. 11 percent). Estimates for tall buildings are based on a small number of responses and therefore subject to large sampling errors. No pattern of asbestos content was found by height.

Table 7-16. Estimated number of buildings with asbestos-containing[a] materials by type of material and building height (in 1,000s) (95 percent confidence limits for key items in parentheses)

Building height	Asbestos-containing sprayed or trowelled on friable material[b]	Asbestos-containing ceiling tile	Asbestos-containing pipe/boiler insulation material	Any asbestos-containing material
1-2 floors	165 (7-324)	0[c]	191	352 (232-473)
3 or more floors	26 (7-46)	2	373	380 (58-703)
All buildings[d]	192 (18-365)	2 (< 6)	563 (239-888)	733 (499-966)

[a]One percent or more asbestos found in laboratory analysis.

[b]Includes friable material applied to surfaces and steel beams.

[c]Less than 500.

[d]May not equal sum of rows due to rounding.

Table 7-17. Estimated percent of all buildings with asbestos-containing[a] material by type of material and building height

Building height	Asbestos-containing sprayed or trowelled on friable material[b]	Asbestos-containing ceiling tile	Asbestos-containing pipe/boiler insulation material	Any asbestos-containing material
1-2 floors	5	0[c]	6	11
3 or more floors	5	0[c]	71	72
All buildings	5	0[c]	16	20

[a]One percent or more asbestos found in laboratory analysis.

[b]Includes friable material applied to surfaces and steel beams.

[c]Less than 0.5 percent.

Table 7-18. Square footage of sprayed- or trowelled-on material, all material and asbestos-containing[a], by building height (in 1,000,000's). Percent of such material which contains asbestos.

Building height	Square footage of sprayed- or trowelled-on friable material	Square footage of asbestos-containing sprayed- or trowelled-on friable material	Percent of material which contains asbestos
1-2 floors	1,592	859	54%
3 or more floors	3,095	325	11%
All buildings[b]	4,688	1,184	25%

[a]One or more percent asbestos found in laboratory analysis.

[b]May not equal sum of rows due to rounding.

SECTION 8

ASBESTOS INSPECTION -- QUALITATIVE REPORT

I. Introduction

The following discussion describes the noteworthy field observations and general characteristics encountered during a survey for friable materials in buildings at ten sampling sites around the United States. The primary objective of this survey was to locate friable materials within selected buildings; in particular, sprayed ceiling coverings, boiler and pipe wrap, and other exposed suspect materials were inspected. Discussion of the selected building sites are based on a thorough review; however, any discussion of the nearby buildings is subjective in nature and is based on the inspection teams' limited observations of the surroundings areas. Only one to two weeks were allowed to inspect approximately two dozen buildings in each area. During this inspection period there was incidental contact with other building interiors and chance cross-sectional area reviews. Regional generalization is even more tenuous since there was even less opportunity for overview from this perspective. Within these constraints, each area is described briefly in terms of its population growth patterns, its economic base, and its weather factors since these provide a functional rationale for the construction practices. Appendix G provides tables giving detailed building descriptions.

II. Northeastern Suburban Area

A countywide area in the Northeast was designated as one of the sampling sites. It is near a large metropolitan area and has a population of about 600,000 although none of its cities exceeds 50,000. Growth and development in the community was steady over the first half of this century but escalated in more recent times. Its economic base evolved from farming and commerce to one prominent in petrochemicals, pharmaceuticals, clothing, electric supply, and service industries. Nonresidential buildings are masonry or brick, one to two stories tall, with flat roofs. There are over 1,200 industrial firms in the county.

Table 1 of Appendix G describes the sampling sites and surrounding buildings in this area. The buildings sampled appeared generally representative of the county's buildings with the exception of the five wooden barracks included. These may have been considerably oversampled for the area.

Most older buildings in the sample have their own central heating systems of the hot water radiation type, usually located in basements. Common heating fuel had been coal with later conversions to oil and gas. Asbestos had been used extensively as a thermal insulation in these systems but many of the inspected units have had recent alterations. New building heating systems are of the forced warm air variety with fiberglass duct insulation.

There appeared to be a general awareness of potential asbestos problems in this area. There were several instances in which inspections had been made previously and removal action had been taken as a result. However, insulation was not replaced in several of these units.

III. Midwestern Urban Area

Another area selected was a large midwestern city. This region has the greatest temperature variation of any of the sections studied. The city was founded in the 1830's and grew steadily through much of that century to a population of 500,000 in 1880. That figure had doubled by 1890. Current population within the city limits exceeds three million with another four million people in the immediate area.

The economic base of the area is diverse and includes equipment and durable goods manufacturing, petrochemical refining, steel production, and agricultural products processing. The city is one of the air, truck, and rail centers of the country. It is located on a large body of water with interconnecting waterways to the Atlantic and the Gulf of Mexico, which further promotes commerce opportunities.

The city is considered a leader in volume of construction and production of architectural landmarks. There are a few buildings that exceed 100 stories in height at the city's center; however, most of the commercial structures are less than 20 stories tall. Outside of this center, most buildings are less than five stories tall with the exception of high rise public housing projects of the 1960's and 1970's and numerous older apartment houses in one area. The premises selected for inspection seemed to be a reasonable cross section of the area's buildings. Table 2 in Appendix G describes the buildings in the area.

Older buildings have furnace rooms in their basements and heat water as a transfer medium. Asbestos-type material is quite common as an insulator in the buildings inspected. There were several areas sprayed with acoustical or thermal insulation material in the premises inspected. This practice, while not very common, appeared occasionally in other buildings of the area.

IV. Midwestern Urban Area B

Another midwestern city was selected that has grown rapidly since just before the turn of the century. Its present population of nearly 0.5 million is distributed over about 600 square miles. Principal industries include oil, computers, defense, farming, and meat processing. There is also a large commitment to education, hospital services, and government administration. The premises in this sample are generally representative of the buildings in the area. The building profile for this area is typically low. Brick, stone, and steel are the usual construction materials. The buildings are typically heated from a central furnace with supplements from space heater arrangements. Pipe wrap and boiler wrap of asbestos-type materials are common in larger buildings. Table 3 in Appendix G describes the buildings in this area.

V. Southwestern Urban Area

Another of the selected sites was a large town and surrounding area in the Southwest. It is a town of relatively new construction though its founding dates to the Spanish colonial era and Indian times. Some of the modern architecture reflects the influence of these peoples. The town began its present growth in the 1880's but, because of hot summer temperatures, its population was modest until the advent of air conditioning.

Its population was:

1950	100,000
1970	581,000
1980	765,000

Electronics and aerospace manufacturing supplement agricultural production and distribution. Retailing and service industries are much in evidence with over 200 shopping centers in the county to serve the residents, tourists, and retirement community. A university of about 20,000 students is nearby.

The buildings sampled are representative of those in the area. The use of area heaters or reverse-cycle air conditioners in this region is widespread because the temperature does not generally drop below freezing. No central furnace rooms were included in sampled buildings. NVAC units were mounted on sides of buildings or on roofs. The practice of texturing ceilings and walls appeared to be common. Table 4 of Appendix G describes the buildings in this area.

VI. Southeastern Rural Area

Another region selected was in the Southeast. This three-county area is fertile farmland and major industries center on tobacco, peanuts, cotton, and soybeans. Timber and some textile manufacture also contribute to the economy. The larger cities in the region are centuries old but contain less than 30,000 people. Most of the towns have less than 1,000 individuals. Nonresidential buildings are typically one story brick structures or two story brick and masonry construction. Newer buildings are commonly steel shell. Table 5 in Appendix G describes the buildings in this area. The sampled buildings appear to be representative of the buildings in this area. Space, area, or radiant heaters are often used in heating these buildings since the winters are relatively mild. Some larger government buildings and stores have central hot water furnaces and asbestos-type insulation has been used with these.

VII. Western Urban Area

A large western metropolitan city was one of the selected sampling sites. The city is located on the Pacific Ocean and has a population of about three million. The economic base is diverse and includes petroleum plants, produce importers and exporters, produce farmers, and many tourist attractions. Commercial buildings are cinder block or brick, one to two stories tall, with flat roofs. Many of these are warehouses with offices in the front.

Table 6 in Appendix G describes the sampling sites and surrounding buildings in the area. The sampled sites are representative of the entire city.

Only two of the buildings inspected had basements. The buildings have little boiler insulation or pipe wrap due to the warm climate. Most buildings have individual forced air furnaces with fiberglass insulation. Asbestos-type fire proofing was used above the suspended ceiling.

There was a general awareness of asbestos in the area even though not much was present. In one instance, sampling and removal had already been completed.

VIII. Midwestern Rural Area

Another selected area was a midwest county with a total population of approximately 70,000. One major town has a population of 45,000 with the smaller towns having less than 1,000 people. The main economic base is farming, mainly wheat, corn, soybeans and milo. The country's largest grain elevator is in this county and crops are shipped by railroad and truck. One community in the county is Amish.

Nonresidential buildings are single story steel framed and brick. Blanket fiberglass insulation is used in the steel framed structures. The majority of the nonresidential and residential sites have a central heating system; fiberglass insulation is used on pipes. The other residential buildings had basements with boilers and pipes insulated with asbestos-type material. The sites selected for inspection are representative of the entire county. Table 7 in Appendix G describes the sites and surrounding areas.

IX. Midwestern Urban Area C

A large midwestern city was another selected area. The population of the city proper is 448,000 and in the surrounding ten-county area is 1.3 million. The economic base is in agri-business, automobile manufacturing, and commercial business.

Nonresidential buildings are one to two story brick structures with and without basements. Central air systems are common although several do have boiler insulation and pipe wrap of asbestos-type material. Residential buildings are constructed of brick and are two to three stories tall. All the residential buildings had basements but only half of the total used a boiler to generate heat. The boiler and pipes present have asbestos-type material as insulation. The other half of the buildings have individual air systems. The upstairs of two residential buildings has been renovated but the boiler has not been touched. One nonresidential building had asbestos-type fire proofing sprayed on the attic.

Table 8 in Appendix G describes the inspected sites and surrounding areas. The entire city was well represented by the sites inspected.

X. Northeastern Urban Area

Another selected site was a large northeastern city with a population of five million. The city is located on the Atlantic Ocean with access to air and waterways to transport freight. The economic base is textile manufacturing, education, import, export, and entertainment.

Nonresidential and residential buildings both were constructed of brick and five or more stories tall. All buildings inspected are 50 to 100 years old with little renovation having been done. The sites all have basements where the boiler is located. The boiler and pipes all have an asbestos-type material used for insulation. Asbestos-type material is used for decorative purposes and as fire proofing above suspended ceilings.

Table 9 of Appendix G describes inspected sites and surrounding areas. The inspected sites are representative of the entire city. Very few merchants know what asbestos is and are unconcerned about it. One site has confirmed asbestos on the ceilings and have encapsulated this area.

XI. Southwestern Urban Area B

A large southwestern city with a population of 1.6 million was another selected site. This city is located in close proximity to the Gulf of Mexico for easy access to the waterways. The population increased during the 1970's from one million in 1970 to the present population of 1.6 million. This was primarily due to the economics of the area. The economic base is petroleum, chemical products, aeronautics, and education.

Nonresidential and residential buildings are all one to two stories tall with only one having a basement. Construction of most buildings is a mixture of wood and brick. There is no boiler or pipe insulation used in this area because of the warm climate. Both nonresidential and residential buildings have either central heating systems or individual forced air systems. Acoustical tiles and asbestos-type fire proofing have been used in several buildings.

Table 10 of Appendix G describes the selected sites and surrounding buildings. The selected sites appeared to represent the entire city. The people were aware of asbestos because of a previous problem.

XII. Qualitative Conclusions

General statements that can be made from the inspections include:

- Inspections of the various types of buildings in this survey for friable material were carried out within a reasonable time frame and for a reasonable cost.
- Samples of suspect material may be obtained without undue disruption of building activities.
- Analyses of suspect material may be readily performed by established techniques through contract laboratories.
- Asbestos-type materials are common on central heating plant components throughout the country. These materials include boiler wrap, pipe wrap, gasket material, flue wrap and couplings.
- Asbestos-type materials appear less common on hot water supply systems including heater jackets, reserve tanks and supply lines.

- Sprayed- or trowelled-on friable material appears distributed across country in three forms -- fluffy, tamped, and granular.

- There appear to be regional differences in the types of sprayed- or trowelled-on friable materials found.

- Ceiling tiles and panels are used throughout the country. Very few contain asbestos.

- Floor tiles and linoleum coverings are used throughout the country. Some may contain asbestos.

- Materials other than those listed above are used in building construction and may contribute to asbestos burden. These include millboard, HVAC couplings, caulking, etc.

- Asbestos-type materials are being rapidly phased out and replaced by cellulose, fibrous glass, and mineral wool substitutes.

- Many building owners have already made asbestos inspections and initiated remedial action.

Regional comparisons:

- The east and midwestern U. S. are more likely to have central heating with furnace/boiler configuration than the South and West.

- Certain areas in the East have an increased consciousness of asbestos hazard and have initiated remedial action on heating systems.

- Other areas of the East have a very common usage of asbestos in existing buildings including sprayed-on materials for acoustical, thermal and fire protection insulation and are not aware of the potential problems.

- The use of suspect asbestos materials is less in the Midwest, West, and South than in the East.

APPENDIX A

FIELD PROCEDURES--CHAPTERS 3-6 OF THE FIELD MANUAL

3. THE BUILDING INSPECTION

3.1 How to Identify Friable Materials

As you conduct the inspection you will be looking primarily for friable material -- material which can be crushed, crumbled or reduced to powder by hand. Friability cannot be determined visually; the material must be touched. In this chapter we describe friable materials and discuss how to identify them. The discussion below is from an EPA Region VII document entitled Asbestos Exposure Assessment in Buildings: Inspection Manual.

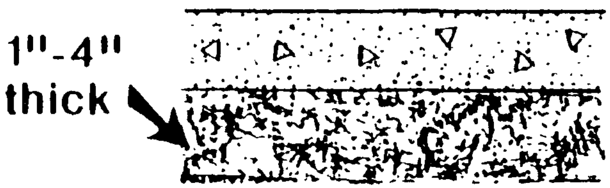
During the past four years, members of the EPA Region VII office evaluated over 600 buildings in Iowa, Kansas and Nebraska, identified as containing asbestos. Inspection of these buildings revealed basically three types of sprayed-on asbestos-containing material (see Exhibit 3-1). One was very fibrous (composed almost entirely of fibers), spongy, fluffy, loosely bonded, highly friable (easily crushed by hand pressure), and one to four inches thick. The asbestos content was usually greater than 10 percent with a maximum asbestos concentration of 98 percent. It had the appearance of cotton candy or Spanish moss hanging from the ceiling and/or walls. This material was usually a mixture of asbestos plus cellulose, rock wool, or fibrous glass which had been spray-applied and in many instances had been tamped (compressed). Several instances were found in which latex or enamel paints had been applied over the asbestos-containing material.

A second type of asbestos-containing material was an essentially non-fibrous, cementitious material commonly referred to as acoustical plaster. The major component of the cementitious,

Exhibit 3-1

DESCRIPTION OF SPRAY-APPLIED ASBESTOS-CONTAINING MATERIAL

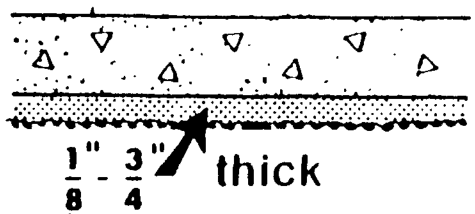
FIBROUS



ASBESTOS IS:

1. Highly Friable
2. Very soft
3. Fluffy & Spongy
4. Loosely bonded together
5. Composed almost entirely of fibers
6. Cotton candy/Spanish Moss appearance
7. Usually contains more than 10% asbestos

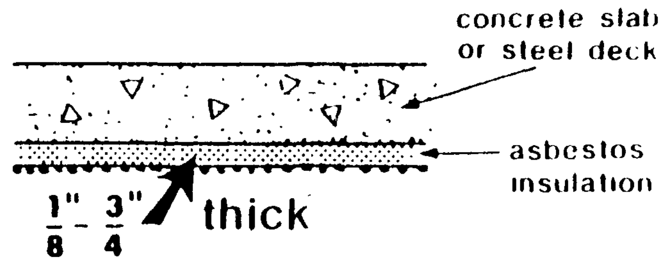
GRANULAR CEMENTITIOUS



ASBESTOS IS:

1. Friable
2. Soft, easily indented by hand pressure
3. Easily rubbed off as powder by hand pressure
4. Non-fibrous mixture of granular material, (only fibrous components are the few asbestos fibers)
5. Densely packed
6. Coarse sand, textured appearance
7. Usually contains less than 10% asbestos
8. Commonly referred to as acoustical plaster

CONCRETE LIKE



ASBESTOS IS:

1. Hard
2. Not friable; can not be damaged by hand pressure
3. Requires mechanical device to penetrate surface
4. Non-fibrous mixture of granular material, (only fibrous components are the asbestos fibers)
5. Densely packed
6. Coarse sand, textured appearance

acoustical plaster was usually a dense, <u>non-fibrous</u> mixture of granular materials such as perlite, calcite, calcium carbonate and vermiculite. The only fibrous component was the asbestos, usually at a concentration of less than 10 percent. This acoustical plaster had most frequently been spray-applied; although, in a few instances it had been troweled on. This material had a coarse sand, textured appearance and was most often 1/8 inch to 1/2 inch thick, with a maximum thickness of 3/4 inch. Such materials were soft and could easily be indented by hand pressure and if rubbed, a powder residue remained on the hand. It was light tan in color if unpainted, but was frequently observed coated with latex paint.

The third type of spray-applied coating was a very hard, concrete-like asbestos-containing material. It also had a coarse sand, textured appearance and was approximately 1/8 to 3/4 inch thick. It was most often used to fireproof structural steel members and was therefore commonly referred to as fireproofing concrete. It did not leave a powder residue on the hand when rubbed and required a mechanical device to penetrate the material.

Other types of asbestos-containing material have been observed in other parts of the United States. An asbestos-containing material having the consistency and appearance of mud is an example of a type of material observed in a Maryland school but, to date, not encountered in mid-western schools and buildings. Therefore, experience may be different in different parts of the country.

Asbestos-containing materials were most frequently encountered in: air handling room(s), boiler room, bathrooms, corridors, garages, and above suspended ceilings. The highly friable, spongy, asbestos-containing material was rarely observed throughout an entire building. In most cases it was observed only in isolated rooms. For this reason, it is extremely important that the entire building be inspected. Schools have been inspected with bare concrete in two air handling rooms only to find the ceiling and walls in the third air handling room coated with two-inch thick asbestos-containing material.

Of all the asbestos-containing buildings examined in the Midwest, approximately 80 percent of the coatings were acoustical plaster having the appearance of textured ceilings and having the consistency of the second type of asbestos-containing material described above. Whenever cementitious, acoustical plaster was found, it had usually been spray-applied on ceilings throughout the entire building. The predominant ceiling construction in mid-western schools was found to be a three coat plaster system on suspended metal lath. The final coat, or finish coat, of this three coat plaster system was the acoustical treatment containing asbestos fibers.

The concrete-like coating was rarely located and usually did not represent an asbestos fiber exposure hazard because the material was not friable.

The use of asbestos as pipe and boiler wrapping is widespread. Damaged asbestos wrapping can easily be rewrapped in canvas or with duct tape.

In summary, friable material is material that can be easily crumbled, pulverized, or reduced to powder in the hand. It may be an asbestos-containing material, or it may be a material that contains other fibers, such as cellulose and fiberglass.

Friable material may be found on the ceilings of office space, corridors, meeting rooms, cafeterias, machinery rooms, and storage rooms. It may also be found on steel support beams and columns, pipes, and occasionally on walls. Neither visual inspection of friable material nor checking building records can determine the presence or absence of asbestos. Such a determination must be made through proper sampling and analysis.

3.2 Building Summary Sheet

The building inspection will be conducted by the field coordinator and the building inspector. The first task will be measuring the outside of the building and preparing the Exterior Map, discussed later.

Next, begin to obtain the information from the building contact which is recorded on the building summary sheet on the next page. The top portion of the summary sheet should be filled in at the start of the inspection. Much of the information in the middle and lower sections is filled in after the inspection is completed.

The following points refer to this data form:

- Year of construction - It is important for sampling purposes to have the specific year of construction. The Advance person has already made sure that the building has been constructed before January 1979. If you find out a later date, check it carefully and call Westat.

- Number of floors should agree with the Exterior Map.

- Number sampled areas. Count the number of areas on all three data forms.

NATIONAL SURVEY OF BUILDING MATERIALS

BUILDING SUMMARY SHEET

Building ID: ______________________ Inspection Date: __________

Building Name: ______________________ Inspection Team: __________

Building Address: ______________________

____

Contact Name ______________________

Title ______________________

Telephone ______________________

Year of Construction: ______________________

SUMMARY DATA:

floors (include basement) __________

maps __________

sampled areas __________

fan/boiler rooms __________

samples taken __________

Q.A. samples taken __________

total square feet of building __________

Type of Construction (check one)

- frame ○
- masonry ○
- steel beam ○
- other ○

Use (check one)

- office ○
- commercial ○
- residential ○
- mixed (specify) ○ __________

COMMENTS: (include comments about major alterations, renovations and additions)

Portion of building not inspected (in sq. ft.): __________ Reason: __________

____

____

- Number fan/boiler rooms should agree with form C.

- Number of samples taken - count the sample I.D. labels on all three data forms (exclude Q.A. samples).

- Total square feet of building should be the result of your measurement and calculations as shown on the Exterior Map. Check with the building contact to make sure your information is nearly the same. If it is not, investigate the reason, recalculate or remeasure.

- Comments - Include other relevant information about the building, especially information about major additions, alterations and/or rennovations.

- Record the square footage of the portion of the building which was <u>not</u> inspected and state the reason and specific location such as establishment names or room numbers.

- Check type of construction.

- Check building use. If mixed give percent of square footage for each type.

4. INSPECTION PROCEDURES

4.1 Fan/Boiler Room Procedures and Data Forms

The first part of the building inspection is the equipment room(s), or boiler/fan room(s). These rooms are usually located in the basement or on the roof of the building but may be anywhere. After you have completed the Exterior Map and top portion of the Summary Sheet, ask the building contact for the location of these room(s). Be sure that s/he identifies all such areas in the building.

The inspection of the b/f room(s) should be brief (not more than 15 or 20 minutes). You will not be required to diagram the inside of the room. Ask that the building contact accompany you to the room(s) to unlock doors and identify different uses of pipes and ducts.

Data Form C, to be used for recording this part of the inspection, appears on the next page. Fill in the ID information and the number of fan/boiler rooms.

Next, observe all areas of the room including the ceiling, the floor, and all pipes, ducts, and boilers to identify friable material. Using the procedures described in Chapter 6, touch, press, or crumble the material. For areas which are inaccessible, ask the building contact if a ladder is available. If not, observe the area from as close a vantage point as possible.

Building ID ____________

Building Name ____________

Form C. Fan/Boiler Room Samples

Number of fan/boiler rooms ____________

Fan/Boiler Room Location in Building Floor #	Area #	Location of Material Ceiling, Wall Other (pipe wrap, boiler insulation, duct insulation, describe)	Condition Code 1 – 5 (1) = Best (5) = Worst	Random ID Sticker*

**Bracket each pair of side-by-side samples*

The following points refer to data form C.

- Location - Describe the location of the fan/boiler room and the floor (i.e. S.W. corner of basement, accessible only from outside). Use ditto marks for additional samples taken in that room.
- Area Number - Number areas sequentially on each form. Use ditto marks if more than one sample is taken in an area.
- Describe location of area within the boiler room.
- Condition code - to be described in detail at training
- Affix a random I.D. sticker to the sample bottle and to this form.
- Take a side by side Q.A. sample for every 10th sample and bracket the pair in the margin.

Friable Material Areas

Note each "different" area of friable material. By "different" we mean either

1. An area that looks or feels different from other F.M. areas (not only in color but in texture).
2. An area which is covering a boiler, pipe, duct, or
3. An area which is covering a pipe or duct which has a different function or is a different size. (Information about the function of pipes and ducts may be obtained from the building contact.)

In regard to (3) above, it is more likely that asbestos-containing material will be used to insulate a heat pipe, so it is important to identify these pipes, when possible and to sample from them.

Next, obtain one sample from each "different" area. In the fan/boiler room, samples should be taken only at locations where no damage will be done by the sampling process. This will either be an area where the pipe lagging or insulation is already damaged or at the end of the pipe where the material stops, and can easily be sampled. Do not damage intact pipe covering.

To help you keep track of when it is time to take a Q.A. sample we have bracketed the right most labels on the ID sticker sheet for every 10th sample. Use the stickers in order - then Q.A. samples will be chosen correctly. Using the stickers in order will also make receipt control easier at the home office. Be sure to affix the stickers to the bottles and data forms immediately upon taking the sample. The other entries in the data form should also be filled out then.

4.2 Walk-Thru Inspection

After the boiler/fan rooms have been inspected you will begin the walk-thru inspection.

The most important point to be made about the walk-thru is that the objective is to observe as much wall, ceiling and suspended ceiling area as possible. You will need to judge which procedures are needed to achieve this objective. For instance, if there is a suspended ceiling and the area above can only be observed by lifting a ceiling tile, remove as many tiles as is necessary to get a clear view of the ceiling to the exterior walls. If you can see beyond rooms from one vantage point, it is not necessary to look above ceiling tiles in each room. It will probably be necessary to use a step-ladder to look and sample above the ceiling tiles. You will also note the presence of vinyl floor tile and will take at least one sample of tile in each building where it is present (in the least consipicuous place).

There may be some areas which cannot be observed such as offices which cannot be entered. Please indicate those areas on the summary form and indicate the reason why the inspection was not possible.

The walk-thru inspection should follow inspection of the boiler/fan room(s). It is not necessary that the building contact accompany you through the building but it may be helpful. In some instances you may need to stand on a desk or use a ladder which the building contact can provide. However, you should have a step-ladder in your car in case you need one and the building contact cannot provide one.

It is most important to conduct the walk-thru as unobtrusively as possible. We want neither to raise curiosity nor to cause any disruption in the building. Be very sensitive to the wishes of the contact person. If he or she suggests that some area of the building should be inspected at a different time follow these suggestions. Be as courteous as possible to anyone you encounter in the building.

Begin the inspection with the lowest floor. Observe walls and suspended ceilings. Be especially careful to observe the areas above suspended ceilings including pipes or ducts. All floors with rooms or equipment or in which building activities take place should be inspected. These would include parking garages and roof top equipment areas.

If the building contact is with you during the inspection and you do observe friable material, ceiling tile, floor tile or pipe wrap, ask for permision to take a sample. If you conduct the walk-thru unaccompanied, ask for permission to sample after the walk-thru is complete. Then, go back and take the sample. Chapter 6 describes the method for determining where to take the samples of material and how to record them on the data forms.

The Edit Check List

Because of the complexity of the data for this survey, it is important that the data folder be checked carefully before it reaches Westat. If items are unclear or missing when the folder reaches Westat, it will be necessary to recontact the field team to supply additional information. The field coordinator may receive assistance and feedback from Westat during regular reporting calls concerning the quality and usability of the data folders. We have provided an edit check list for each building. Please check these items carefully and return the check list in the folder.

On the back of the edit check list is space to record the building owner's request for information and address.

Building Name: ______________________ # Data Form A________

B________

C________

Residential Forms ________

Edit Check List

I |_| Check all items on summary sheet are complete and accurate.

|_| Check building ID on <u>all</u> pages.

|_| Be sure that all maps are numbered sequentially and that there is an exterior map and a map for each sample listed on Form A and for floor tile on Form B.

II **Exterior Map**

|_| Check to see that diagram is understandable and that all exterior dimensions are clearly marked.

|_| Check to see that number of floors is clearly marked and includes basement.

|_| Check to see that total square feet calculation is clear and accurate.

III **S.A. Maps**

|_| Check to see that all information on top of page is filled out.

|_| Check to see that area location is as specific as possible.

|_| Check to see that random coordinate calculations are clear and that the samples are clearly marked with an X.

|_| Check to see that the square feet calculation is clear and accurate.

IV **Data Forms**

|_| Check all columns on all data forms. Be sure that Q.A. samples are bracketed.

|_| Be sure that the specific place where the sample was taken is recorded so that the sample spot may be identified to the building owner by room number, floor number, etc.

|_| Be sure that all information from the maps agrees with the information on the data forms.

4.3 Preparation of Maps

Two types of maps will be prepared by the inspection team, the exterior map and the sampling area maps. The maps allow the home office to recalculate dimensions and to locate the spots where samples were taken. It is important that the maps contain all the information discussed below but not be more detailed than necessary. In general, it is not necessary to:

- Draw the maps to scale.
- Include doors or windows.
- Include rooms on exterior map.
- Include separate establishment names on exterior map.

The data we want to collect and verify by examination of the maps is the following:

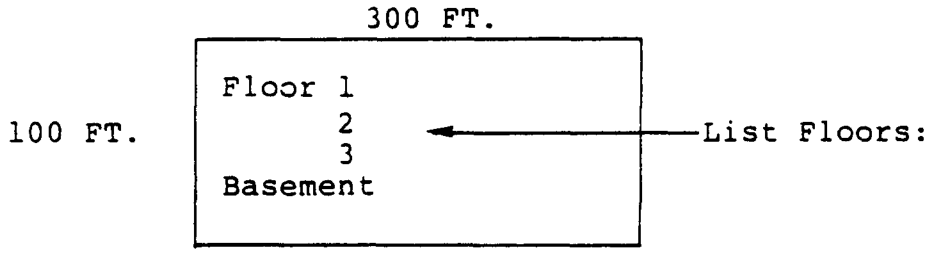
1. The total square footage of the building (the Exterior Map), and
2. The dimensions, sample location and sample procedure for each sampling area (S.A. map).

Information from the maps will be used to verify and supplement the information on the data forms. It will be the responsibility of the Field Coordinator to see that information from the maps agrees with information on the forms and that the information listed above is clear and accurate.

Maps for a building should be completed and edited before the next building inspection.

4.3.1 <u>The Exterior Map</u>

The purpose of the exterior map is to show the dimensions of the building from which square footage was calculated. This map does not need to be to precise scale but should show the basic shape(s) of the building (i.e. square or rectangular).



When the building contains only one floor or when all floors of the building are alike, the square footage of one floor can be calculated then multiplied by the number of floors. By "alike" we mean that they all have the same exterior dimensions, not that the rooms, hallways, or usage is alike. List floors of the same shape in the diagram.

If all the floors of the building are not alike, sketch each shape and indicate the dimensions of all floors on the same map. Identify each floor on the map.

For instance, the example on the next page is a map of a discount clothing store. The second floor is open to the first like a balcony. Using the Exterior Map, you can both calculate the square footage of the building and describe its layout.

The most important point about the Exterior map is that a coder at Westat should be able to recalculate total square footage of the building by looking only at the map page.

Other information which must be included on the Exterior map is the following.

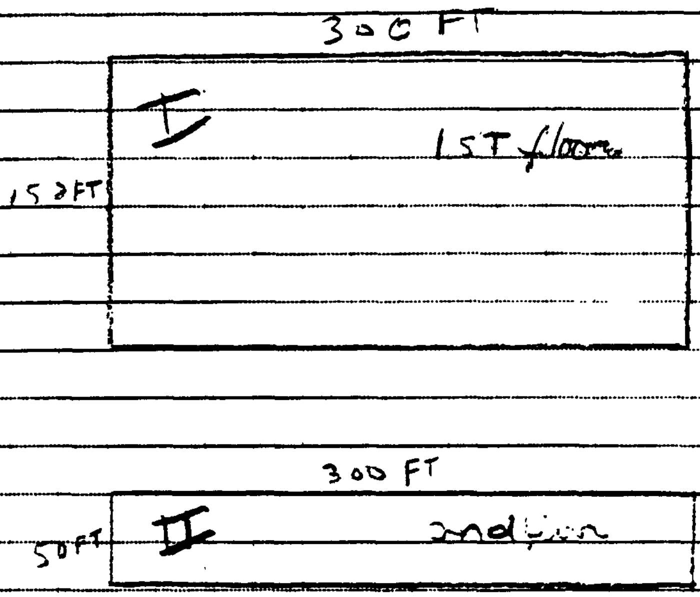
- Map number -- number all maps sequentially with number 1 being the Exterior map.
- Building name.
- Building I.D.
- Square foot calculations (as above) at the bottom of the page.

In some buildings, building plans or blue prints may be available. These plans can be useful in helping you draw the

Exterior Map

Map # 1 Bldg. ID 300501 Bldg name Kornettes

SKETCH EXTERIOR SHAPES WITH DIMENSIONS



Square Feet Shape I (show calculations)

300FT X 150FT= 1 X number of floors = TOTAL [illegible]

Shape II

300FT X 50FT= 1 X number of floors = TOTAL [illegible]

Shape III (Record additional shapes on back)

X number of floors = TOTAL ______

Total square feet of building (sum shapes) (include basement)

45,[illegible] + 15[illegible] + ______ = 60[illegible]

TOTAL SQUARE FEET

Exterior map. Please do not substitute these plans for maps but please include them in the data folder.

4.3.2 Sample Area Maps

In addition to the Exterior map, you will prepare a map for each sample area which is located outside a fan/boiler room. These samples are listed on Forms A and B. It is not necessary to prepare maps for samples taken in fan/boiler rooms or for samples of pipe or duct wrap taken outside fan/boiler rooms.

The purpose of the S.A. map is to show the dimensions of the SA, where samples were taken and the procedure used to select the spot. Samples will be taken in spots chosen by a random number procedure (except for floor tile and ceiling tile) unless it is impossible to do so.

At the bottom of each S.A. map page, one of two things should be recorded:

- Calculations showing how the random coordinates were chosen,

OR

- The reason why a convenience sample was taken.

The S.A. map is a diagram of a homogenous area of material. For instance, if a homogenous area covers a ceiling and extends down the wall, the wall and ceiling would be considered one area and would be drawn on the same map.

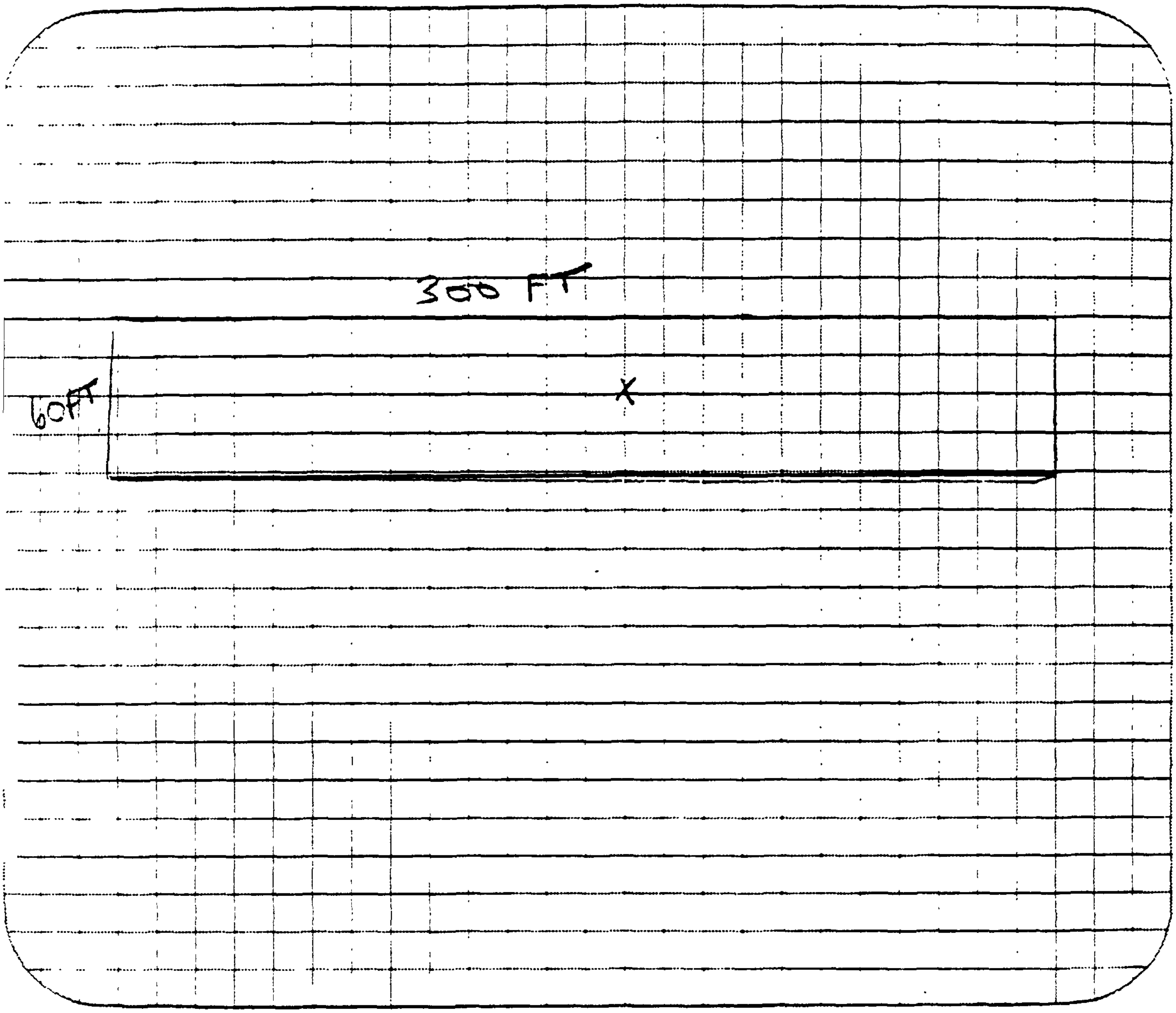
Sampling Area Map

lap # 2 Area # 1 Bldg ID 300501 Bldg name Korvettes

Location entire ceiling Floor # 2

SKETCH AREA WITH DIMENSIONS

MARK SAMPLES WITH X



Total area height 60FT X width 300FT = Total square feet of area 18,000

					IF CONVENIENCE SAMPLE, RECORD REASON
RN ______	X	ht ______	=	______	ceiling could not be damaged. Sample was taken under a light fixture
RN ______	X	width ______	=	______	
RN ______	X	ht ______	=	______	
RN ______	X	width ______	=	______	
RN ______	X	ht ______	=	______	
RN ______	X	width ______	=	______	

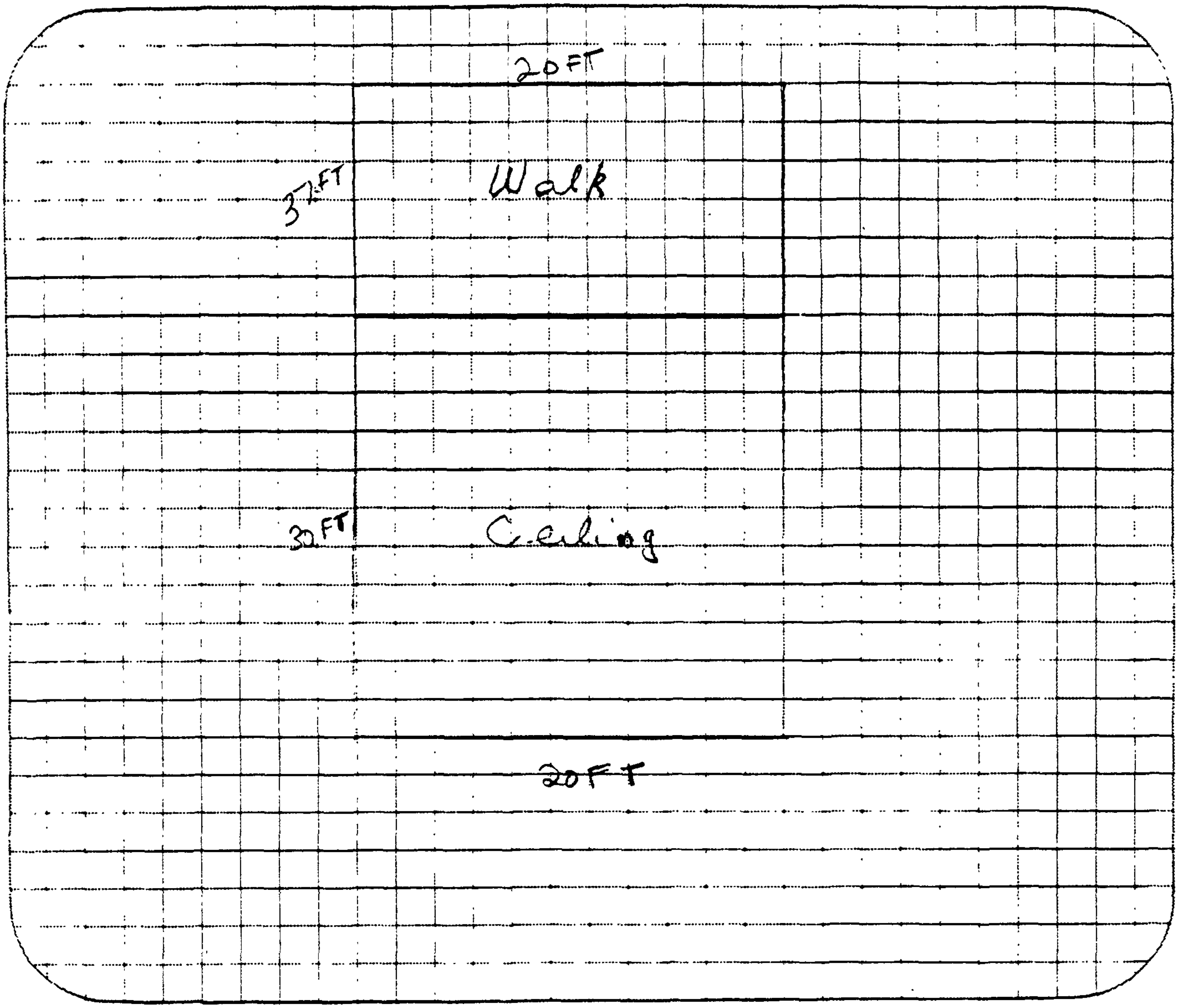
Repeat on back for additional samples

Sampling Area Map

Map # ______ Area # ______ Bldg ID ______ Bldg name ______

Location Ceiling [illegible] 229 Floor # [illegible]

SKETCH AREA WITH DIMENSIONS
MARK SAMPLES WITH X



Total area height 37 FT X width 20 FT = Total square feet of area 740

RN ____ X ht ____ = ____ RN ____ X width ____ = ____	IF CONVENIENCE SAMPLE, RECORD REASON
RN ____ X ht ____ = ____ RN ____ X width ____ = ____	Decorative material [illegible]
RN ____ X ht ____ = ____ RN ____ X width ____ = ____	

Repeat on back for additional samples

The diagram should show the shape of the area with the dimensions clearly marked. It should also identify the location (i.e. ceiling or wall) and the location within the building (i.e. 1st floor lobby) as in the example on the next page.

An 'X' will be used to indicate where samples were taken. Sample locations, Quality Control Samples, and sample identification are discussed in Chapter 6. Using the procedures described, show the calculations used to select samples at the bottom of the S.A. map. If, for some reason, you cannot take a sample by random coordinates, draw an arrow to the 'X', identify it as a 'convenience sample,' and explain the reason why the samples could not be taken by random coordinates (i.e. "the wall could not be damaged except under a light fixture").

S.A. maps should each have a map # and each sampling area should have an area number. These numbers will also appear on the data forms so that we can identify the map that shows the location of each sample.

In addition, each S.A. map should have the building I.D. and building name in the upper right hand corner. Examples of a completed set of maps and data forms appear as an Appendix.

5. RESIDENTIAL BUILDINGS

Since residential buildings are by definition where people live, we have developed special procedures for inspecting them to minimize the intrusion into people's living quarters. We will inspect a sample of apartments rather than every apartment. In order for us to make estimates for the entire building based on a sample of apartments, it is important that these procedures be carefully followed and that all the relevant data be collected and recorded accurately and completely. Another special aspect of those residential buildings found in apartment complexes involves boiler rooms. This section of the manual details three special procedures that may be needed for apartment buildings. In Section 5.1, we review the special procedures, describe when each one is used, and tell how to fill out the Residential Building Data Form. In Section 5.2, we describe how to select two apartments for inspection on one floor using the Worksheet for Sampling Two Apartments on One Floor. In Section 5.3, we explain how to select five floors in a multi-floor building.

5.1 Residential Building Data Form

The Residential Building Data Form (Exhibit 5-1) is designed to give us the information we need to estimate building information from the inspection of sampled apartments. It will also assist you in collecting the proper information and inspecting the correct parts of the building.

In describing residential building inspections, we concentrate on the differences from other building inspections. One potential difference is that you may have to schedule your

Exhibit 5-1

SURVEY OF PUBLIC BUILDINGS

Residential Building Data Form

Building ID: __________ Page 1 of __

Building name: ______________________________

I. Building is: a single building |__| (go to III)
part of a complex |__| (go to II). (Check one)

II. Boiler room information for a building in a complex.

A. Every building in the complex has its own boiler room:

Yes |__| (go to III)

No |__| (go to B)

B. There are no boiler rooms in any building in the complex.

Yes |__| (go to III)

No |__| (go to C)

C. Boiler rooms in one building of the complex serve other buildings in the complex.

Yes |__| (fill in data below)

No |__| (go to D)

Name of building housing boiler room that serves sampled building:

____

List all buildings served by this boiler room: __________

____

____

____

D. None of A, B, or C. Use this space and back to describe the situation.

____

Residential Building Data Form (Continued)

Building ID: __________ Page ___ of ___

Building name: ______________________________

Section _____ of _____.

Describe location of section: ______________________________

____

____

III. Floors selected:

A. Number of floors with apartments: __________

Five or fewer |__| (go to IV)

More than five |__| (go to B)

B. Designate sample floors (Attach Worksheet)

__________, __________, __________, __________, __________

IV. Apartments selected: (Attach Worksheet)

Floor	Apt. #	Floor	Apt. #

The apartments selected were inspected:

Yes |__| (end of data form)

No |__| (go to V)

Residential Building Data Form (Continued)

Building ID: __________ Page ___ of ___

Building name: ____

V. Apartments inspected:

Floor	Apt. #	Replaces Apt. #	Comments

Comments: (Information about additions, alterations, renovations, or lack thereof is especially relevant to a judgment of the likely "representativeness of a given apartment.) ______________________________________

inspection of apartments for a later time. Often, the manager of an apartment complex may be willing to allow you to begin the inspection but may ask for a few days to notify tenants before you inspect apartments. If this situation occurs, you should be able to fill out the Residential Building Data Form and draw the sample of apartments at your initial visit. The apartment inspections would be all that remained for the second visit.

Much of the residential building inspection is similar to all inspections. You begin with the exterior map of the sampled building, and you fill in the building summary sheet information in the same way described in Sections 3.2 of this manual. Next, as usual, you turn to the boiler room inspection. This represents the first special procedure for residential buildings. Parts I and II of the Residential Building Data Form collect the relevant information and guide you through the procedure.

5.1.1 Boiler Room Inspection

Residential Building Data Form, Part I: In Part I, you simply check the appropriate box as to whether this building was sampled as a single building or as part of a complex. This information will be stated on the advance sheet, and if the building is part of a complex, a sketch map will have been drawn showing all the buildings in the complex. Be sure you have the sketch map with you when you visit the building. If this is a single building, you can skip Part II of the data form. Cross it out with a large X. Inspect whatever boiler/fan rooms there are in the sampled building following the procedures laid out in Section 4-1 of this manual. If the building is part of a complex, you must fill in Part II of the data form.

Residential Building Data Form, Part II: If the building is part of a complex, there may be only one boiler room serving several buildings in the complex. If that is the case, we want to inspect the boiler room serving our sampled building regardless of what building that boiler room is in. We ask three questions in Part II so that you can record the information we will need to know regarding where the inspected boiler room was.

Question A is: does every building in the complex have its own boiler room? If the answer is yes, check that box and you are finished with Part II. Inspect the boiler room in the sampled building. If the answer is no, check that box and go to Question B.

Question B states: There are no boiler rooms in any building in the complex. This is a rare situation; either the machinery is in a separate shed (not one of the buildings in the complex) or it is in some building completely outside the apartment complex. We do not expect this, but if it happens, check yes. There will be no boiler room to inspect and you would proceed to Part III of the data form. If this rare situation did not occur, check no, and continue to Question C.

Question C describes the remaining possibility: Boiler rooms in one building of the complex serve other buildings in the complex. Notice that to get here you have checked no to A and B. Therefore if C is also no, you have to describe the situation for us in D and call Westat to determine which boiler room to inspect. If you are in the situation described in C, you must fill in the following information: What building houses the boiler room serving the sampled building; what are the buildings this boiler room serves? We need enough description and clear notes on the map so that we will be able to go back to the original listing sheets and find each specific building. Street addresses, building names, or building numbers may all be appropriate. Sometimes a list of the range of apartment numbers in a given building will identify the buildings. It is better to identify a building three ways if this is possible than risk choosing a different identifier from the one we have on record. After filling out this information, inspect the boiler room that serves the sampled building according to the usual boiler room inspection procedures. Be sure to state on the form both the sampled building information and some information about the building where the boiler room is located, as well.

5.1.2 Further Inspection

After you have completed the boiler room inspection you are ready to inspect the rest of the building. Inspect all public areas such as lobbies, laundry rooms and hallways as you would any building. But, as we stated earlier, you are not to inspect all the apartments. We want you to inspect two apartments per floor on up to five floors for each homogeneous section of the building. Thus, a maximum of 10 apartments per homogeneous section will be inspected. In Sections 5.2 and 5.3 below, we give detailed instructions for randomly selecting five floors from a larger building and two apartments per floor. Your first task is to determine whether the building is homogeneous or whether it contains two or more sections. This determination can be based on exterior appearance, interior clues such as a step up in a point in the hall on each floor, information from the building manager about construction dates, and major additions, alterations and renovations. If the building contains more than one section, fill out Parts III, IV, and V of the data form for each section of the building. Be sure to number the pages carefully. When the entire building is homogeneous (the usual case), write Section 1 of 1 and "whole building" at the top of Part III of the form.

Now fill in Part III for one section (or the whole building). Fill in the number of floors with apartments. If the building has a basement with no apartments in it, or several levels of parking garage, do not count these floors. Count only those floors with apartments. Now check the appropriate box in Question A. If there are five or fewer floors with apartments, you will select two apartments to inspect from every floor. Go on to Part IV of the form. If, however, there are more than five floors with apartments, you will have to select five floors at random using the Worksheet for Selecting Five Floors. The selection process is explained in Section 5.3. Write down the five selected floors in the space provided in Question B and include the completed worksheet with this data form in the data folder.

After you have five (or fewer) floors, either all floors in a low-rise building or through sampling, go to Part IV. List the five (or fewer) floors in the column labeled "floor" of the table. You are now ready to draw two apartments from each floor using the Worksheet for Sampling Two Apartments from One Floor. The process is explained in Section 5.2. Record the selected apartments in column 2 and include the worksheets with the data form.

The next task is inspecting the selected apartments. You may be able to inspect these apartments by approaching the tenants directly for cooperation. If the apartment manager prefers, you may have to schedule a second visit so that tenants can be notified in advance. After you inspect the selected apartments, check the "yes" box at the end of Part IV. In some cases, the manager may not cooperate with any inspection of the selected apartments, but will allow inspection of vacant or model apartments, or the apartment occupied by the manager. In this case, if you are convinced that the apartments are similar throughout the building, inspect the offered apartments rather than considering the building a refusal. If this occurs, check the "no" box at the end of Part IV. Go on to Part V to document which apartments were inspected; and write down any information supporting the assumption that all apartments are similar. Since it is statistically more valid to inspect the sampled apartments, proceed as if you will do this. Only when meeting with strong objections will you inspect apartments suggested by the manager.

The actual apartment inspections proceed in much the same fashion as the usual building inspection. Any friable material, ceiling tile, or floor tile found must be mapped and sampled. The place where the sample was taken must be clearly discribed and marked on the map. However, if the same material is found in all apartments, additional samples need not be taken after the first apartment. The map for the sample(s) taken should include the areas of all apartments in which the same material was found, labeled by floor and apartment number. Pipe wrap samples should be documented with where they were taken. After inspecting all the selected apartments, make sure you have collected all the necessary data and thank the apartment manager for his time.

5.2 Sampling Two Apartments on One Floor

In this section we explain how to use the Worksheet for Sampling Two Apartments on One Floor (Exhibit 5-2) to do just that. For each floor you will need one copy of the worksheet. Fill in the building ID and name (or address) and the

Exhibit 5-2

Worksheet for Sampling Two Apartments on One Floor

Building ID: __________

Building name: ____

Floor: __________

Number of apartments on floor: __________

Line #	Apt. #	Line #	Apt. #	Line #	Apt. #
1		21		41	
2		22		42	
3		23		43	
4		24		44	
5		25		45	
6		26		46	
7		27		47	
8		28		48	
9		29		49	
10		30		50	
11		31		51	
12		32		52	
13		33		53	
14		34		54	
15		35		55	
16		36		56	
17		37		57	
18		38		58	
19		39		59	
20		40		60	

Random number = __________, Apt. # = __________

Random number = __________, Apt. # = __________

floor you are working on in the lines provided. Either using information provided by the apartment manager or walking through the entire floor, write down all the apartment numbers for apartments on this floor in the columns labeled "Apt. #" starting with line 1 and continuing down each column in turn. If there are more than 60 apartments on the floor, use another copy of this form. Write and fill in Page ___ of ___ on the first and all subsequent sheets. You will also have to renumber the lines on the continuation sheets. When you are done, fill in the blank for "number of apartments on floor" at the top of the form (page 1).

Now, draw random numbers to select two apartments. There are separate instructions for a total of 10 or fewer apartments and 11 or more.

Ten or few apartments: Use one digit at a time from your random number table. Start with the next digit after the last one you used. If it is 0, consider it equal to 10. If the number is the line number of an apartment, circle the number in the table, write down the random number at the bottom of the worksheet, and write the apartment number for that line. If the number is a line number with no apartment, cross it off in the table and look at the next digit. Treat this digit the same way, continuing until an apartment is selected.

To pick the second apartment, follow the same instructions except that if the line number of the first apartment you selected comes up again, cross that number off in the table and look at the next number.

Eleven or More Apartments: If there are 11 or more apartments, look at pairs of digits in the table. Zeros count the usual way: "03" is three; "30" is thirty. But "00" is one hundred. Again, begin with the next pair of digits after the last use of the table. If the pair is the line number of an apartment, circle it in the table, record it on the data form, and write down the apartment number on the form. If it is a line number with no apartment (higher than the number of apartments) cross out the pair of digits and look at the next pair. Continue until an apartment is selected. The second apartment is selected the same way, with the additional instruction that if the line number of the apartment already selected comes up again, cross it off and look at the next pair of random digits.

Transfer the selected apartment numbers to the Residential Building Data Form, Part IV.

5.3 Selecting Five Floors

In this section we describe how to use the Worksheet for Sampling Five Floors (Exhibit 5-3). This is to be done when a residential building has more than five homogeneous floors. Begin by filling in the building ID and name (or address). Label the first page "page 1." List all the floors in the building or homogeneous section that contain apartments (do not list floors with no apartments). You will have to fill in the front digit(s) of the line numbers after all floors are listed. The form is designed so that the same form is used for page 1 and continuations. On all continuation sheets, include the building ID and name, and number the page. On page one in the first column, half-way down, fill in ten 1's and a 2 to make line number 10 through 20. In the second column, fill in nine 2's, ten 3's, and a 4 for line numbers 21 through 40. Continue in this way for all line numbers used to list floors. Once all floors are listed, write the number of floors in the space at the top. This should equal the highest line number. Next, draw the five

Exhibit 5-3

Worksheet for Sampling Five Floors

Building ID: __________ Page ___ of ___

Building name: ______________________________

Number of floors containing apartments: _________

1. Random number: __________ = Floor #: __________
2. Random number: __________ = Floor #: __________
3. Random number: __________ = Floor #: __________
4. Random number: __________ = Floor #: __________
5. Random number: __________ = Floor #: __________

Line #	Floor #	Line #	Floor #	Line #	Floor #
1		1		1	
2		2		2	
3		3		3	
4		4		4	
5		5		5	
6		6		6	
7		7		7	
8		8		8	
9		9		9	
0		0		0	
1		1		1	
2		2		2	
3		3		3	
4		4		4	
5		5		5	
6		6		6	
7		7		7	
8		8		8	
9		9		9	
0		0		0	

random numbers that are the line numbers of the selected floors. Use sets of one, two or three digits from the table depending on whether there are fewer than 11, 101, or 1001 floors listed. When drawing one digit, let "0" = 10; when drawing pairs, let "00" = 100; and when drawing triples, let "000" = 1000. The procedure is simple. For illustrative purposes, we describe it using pairs of numbers to draw a line number between 1 and 47. Taking the next unused pair of digits in the table, if they form a number between 01 and 47, say 33, we circle the pair in the table (to denote that they were used), write "33" as the first random number, and copy the floor recorded on line 33.

Move on to the next pair of digits. If it is not between 1 and 47, or if it equals 33, we cannot use it. Cross out the pair of digits (to indicate they have been used) and examine the next pair. Continue looking at pairs of digits, crossing out any that are out of range or repeats, until five pairs of digits have been circled and recorded on the worksheet.

Fill in the floors that have been thus selected and transfer the list of sampled floors to Parts III and IV of the Residential Building Data Form.

6. RECORDING SAMPLING AREAS ON MAPS AND SAMPLING: OUTSIDE FAN/BOILER ROOMS

As you conduct the inspection, when you find material to be sampled you will record its location by sketching the area it covers on the scale map. After the different areas have been identified, you will determine the random locations for sampling and take bulk samples. The procedures for these activities are based on the EPA guidance document <u>Asbestos-Containing Materials in School Buildings</u>, adapted to the type of building we are studying. You will sample the follow areas:

1. Friable material areas
2. Ceiling tile
3. Floor tile

Ceiling tile, floor tile and pipe wrap will be sampled by convenience, that is, the inspector selects the most convenient spot to take a sample. Friable material samples will be selected by random coordinate procedures.

The following chart shows procedures for sampling from different materials.

Sample Areas	Draw Map	Random Sample	Sample by Convenience
		Outside Fan/Boiler Rooms	
Floor tile	x		x
Ceiling tile	x		x
Pipe wrap, boiler and other insulation			x
Friable material ceilings or area walls	x	x	
		Inside Fan/Boiler Rooms	
Friable material			x
Pipe wrap and insulation			x

The following section contains a discussion of the procedures used for selecting a random sample.

6.1 Record Friable Material on Maps for Sampling

Following the inspection for friable material, establish Sampling Areas. A Sampling Area is defined as a homogeneous area of friable material -- that is, all friable material in a single Sampling Area is of the same type and was applied during the same time period.

The procedure for establishing Sampling Areas is described below. Their proper establishment is extremely important as incorrectly established Sampling Areas will yield results that do not accurately reflect the asbestos content of the friable material in the building. This will bias the results of our study.

Partition the total friable material area of the building into Sampling Areas. The partitioning will be based upon visual inspection, knowledge of the building's history, and building records, if available.

The following example should clarify the method of partitioning.

> Example: Suppose that friable material is found on the ceiling of a large meeting room in an office building and on the ceilings of first floor offices of a wing constructed six years after the main building, where the meeting room is. The friable material on the meeting room ceiling appears to all be of one type, and the friable material on the ceilings of the offices in the new wing appears to all be of a second type. In this situation, two Sampling Areas are required: (1) meeting room ceiling and (2) ceilings of first floor office of the new wing. An estimate of the percentage of asbestos present will be obtained for each of these Sampling Areas. The total square feet of each area will also be estimated based on your scale maps.

For each Sampling Area, diagram the area covered by friable materials. The Area should be marked off as follows:

(1) Clearly indicate the approximate dimensions of all building areas covered by the F.M. Sampling Area. If these measurements are not readily available, measure the area with a tape measure.

(2) Indicate on the diagram any areas that are inaccessible for the purpose of sampling the friable material.

Large Areas

If one Sampling Area contains friable material areas that are not adjacent (for example, areas on different floors of the building where the material is the same), sketch each separate section on the same map according to the above instructions. The Sampling Area may include areas that are not in the same plane (for example, a ceiling and a wall with the same type of friable material). In this case, draw them on the same map and label them clearly (as in the following example).

On Data Form A (on the next page), the Friable Material Form, record the information on the label of each map. The first column of Data Form A is very important for the purposes of reporting back to the building owner. Consider a telephone conversation in which EPA informs the owner of a large office building of the presence of asbestos in a certain location. First, they would need to describe the location of the area, (i.e. third floor, Rooms 339, 340, 342, East Wing). Next, in such a large area, they would need to be able to say that the samples were taken in Rooms 340 and 342. In other words, in large sample areas where the area is not all in one room, list the location of each sample taken.

Number each area consecutively for each form (A, B, C). If additional copies of a form are used, follow on with the next number. Draw a line under each separate area.

Record the location and total square footage of the area. Exposure, type of material, and condition will be described in detail in training. Record whether the sample was selected by plotting coordinates or by convenience, and assign a random ID sticker. Take a side by side Q.A. sample for every 10th sample as indicated on the sticker sheet, and bracket the side by side on the form.

Data for floor tile and pipe wrap samples are recorded on Form B. One sample should be taken in an area which is already damaged or in which damage will not show. Assign a map #

Building ID ______________________

Building Name ______________________

Form A. Friable Material Areas (ceiling, walls, other) and Ceiling Tile Area Samples Outside Fan/Boiler Rooms

(take only convenience sample of ceiling tile)

Map *	floor * room * apt. * etc.	Area *	Location: ceiling, wall, ceiling tile, other	Total square feet	Exposed Yes (1) No (2)	Type of material: 1 - fibrous 2 - granular cementicious 3 - concrete-like	Condition Code 1 – 5 (1) = Best (5) = Worst	Selection (1) Plot (2) Conv	Random ID Sticker*

*Bracket each pair of side-by-side samples

Building Name ________________

Form B. Floor Tile and Pipe Wrap Convenience Samples Outside Fan/Boiler Rooms

(one sample per area, plus Q. A. samples when taken)

FLOOR TILE

Map #	Floor # Room # Apartment # etc.	Area #	Total Square Feet	Random ID Sticker*

PIPE WRAP

Area #	Floor # Room # Apartment # etc.	Describe Pipe or Duct	Condition Code: 1 – 5 (1) = Best (5) = Worst	Random ID Sticker*

*R[illegible] that each pair of side-by-side samples for floor tile, clearly identify the location in the building and the total square footage. Assign an area number and a Random ID sticker. Take a Q.A. sample for every 10th sample taken. Bracket those samples.

Pipe wrap will not be mapped but will be assigned an area number. It is also very important to describe the pipe or duct and its location.

6.2 Determining Sampling Locations

The use of a random sampling technique is especially critical to the validity of our study results. The importance of this aspect cannot be overemphasized.

Since it is clearly not reasonable to remove all the material from a ceiling to examine for the presence of asbestos, a few small specimens and sample of the ceiling material, are taken. The basis for extending the results of the sample to the entire ceiling is statistical theory which assumes random sampling.

Given the wide variation in asbestos content observed in some ceilings, a judgemental or convenience sampling method has led to incorrect characterization of the material. In some cases, the asbestos was entirely missed. In other cases, it was significantly over-estimated.

The number of samples to be collected will be based on the overall size of the Sampling Area. From the dimensions recorded on the Sampling Area diagram, compute the total square feet in the Sampling Area, recording it on Data Form A. Then from the table below, determine the number of samples to be collected.

If the size (square feet) of the Sampling Area is	Then the number of samples to be collected is
Less than 1,000	3
Between 1,000 and 5,000	5
Greater than 5,000	7

If a Sampling Area extends over several floors, some additional steps must be taken to spread the samples across the floors. However, since this complex situation will not occur often, we proceed to describe sampling an area on one floor. After those instructions we will return to the question of areas extending to more than one floor.

After preparing the diagram and determining the number of samples to be collected in Sampling Area, determine the approximate location of each sample. The method for selecting sample locations described below utilizes a TABLE OF RANDOM DIGITS. This is designed to eliminate any inadvertent bias which would jeopardize the correctness of the final decision as to whether or not asbestos is present. Unfortunately, this method involves a certain amount of numerical work. No other method of site selection, though, can guarantee unbiased results. Following this step-by-step procedure carefully will give reliable, unbiased sample site selections.

Select sample locations according to instructions (1) through (6) below. It is very important to properly use the random number procedure to select locations.

(1) Construct on the Sampling Area map an imaginery rectangle enclosing the entire Sampling Area. Diagram with a dotted line. Record the dimensions of this imaginary rectangle below.

(2) From the TABLE OF RANDOM DIGITS, choose a pair of four-digit random numbers. Record the random numbers on the by RN on map. A TABLE OF RANDOM DIGITS is provided at the end of this chapter. Cross out numbers as they are used. Choose a random digit number. Put a decimal point in front of the number, multiply the numbers by each dimension.

(3) The calculated coordinates (2) describe a location within the rectangle. The first number of the pair specifies the number of feet from the bottom of the rectangle, and the second number specifies the number of feet from the left side of the rectangle. The point should be plotted on the Sampling Area diagram.

(4) If the point described by the random number pair is within the Sampling Area and not within any area designated on the diagram as inaccessible for the purpose of sampling, then that point is a sample location. Otherwise, the point is not a sample location. Cross it off and start again.

(5) Continue using the above random number pair procedure until the required number of appropriate sample locations have been selected. Repeat on back of page for additional samples.

(6) All calculated coordinate pairs should be recorded on the map.

<u>Multi-Floor Sampling Areas</u>

In multi-floor sampling areas, we want to spread the sample locations as evenly as possible across floors. In this section we describe how to do that. If a sampling area includes area on several floors, proceed as described above to map all the floors on one S.A. map. Calculate the total sqaure footage and determine whether three, five or seven samples are to be taken. Calculate the coordinates for the first sample according to step (1) - (6) above.

As you calculate coordinates for the second sample, in step (4), if the point is on the same floor as the first sample, do not use this point as a sample point. Cross it out and try again.

Continue on, accepting only sample points that fall on a new floor. If there are fewer floors than the desired number of samples, after you have drawn one point from each floor, the next sample can fall on any floor. Then you would exclude locations on floors that already have two points. In this way, the three, five or seven sample locations will be spread as evenly as possible among the floors, but will still be randomly determined with the correct probabilities.

6.3 Sample Collection

Collect the bulk samples, i.e., samples taken from the friable material by penetrating the depth of the friable material, at the specified locations according to the following guidelines:

(1) Gently twist the open end of the sampling container into the material. A core of the material should fall into the container. A sample can also be taken by using a clean knife to cut out or scrape off a small piece of the material and then placing it in the container. Be sure to penetrate any paint or protective coating and all the layers of the material. If the sampling container cannot penetrate the material, consider whether the material is really friable or not.

(2) Tightly close the sampling container; wipe its exterior with a damp cloth to remove any material which may have adhered to it during sampling.

(3) Tape the sampling container cap to prevent the accidental opening of the container during shipment or handling. In addition, it is recommended that each container be placed in a sealed plastic bag because film canister caps, even when taped, may come off in transport.

(4) Use one computer-generated label on the sampling container. Use the other copies to record the unique sample ID numbers on the data forms, and the lab transmittal sheet to Westat and to the lab.

Collect samples at (or as close as possible to) the selected locations and collect all samples. Exact measurements (i.e., by ruler) are not necessary for finding the sample locations. Quicker, easier techniques such as pacing may be employed. If for any reason the sample cannot be taken at the random spot, take it as close as possible. Note on the map the selected spot and the actual location, and record the reason on the map.

Precautions to be Taken During Sampling

To avoid causing unnecessary exposure to asbestos fibers, take the following precautions while sampling friable materials.

(1) Sample the material when the area is not in use.

(2) Have only those persons needed for the sampling present.

(3) Hold the sampling container away from the face during actual sampling.

(4) Do not disturb the material any more than necessary.

(5) Spray the material with a light mist of water to reduce fiber release during sampling.

(6) Wear a respirator if moving ceiling tiles or in any other way disturbing possible fallen asbestos or its debris.

(7) If pieces of material break off during sampling, wet mop the areas where they have fallen.

APPENDIX B

DATA FORMS

NATIONAL SURVEY OF BUILDING MATERIAL

Advance Form   Government Building Sample

Building ID#: ______________________________

Building or establishment name: ______________________________

Building address with building #: ______________________________

____

____

50% or more government use (verify) |__| |__| call Westat.

Number of floors: ________________

Describe building:

Information from Westat telephone contact:

contact person: ________________ title: ________________

telephone: ____________________

scheduling information: ______________________________

other:

Mixed use buildings (record % and description)

______% residential:

______% government:

______% commercial:

National Survey of Building Materials
Advance Form

Residential Building
Sample

Building I.D.

Building #

Complex or building name ______________________________

Address ______________________________

____

____

Number of apartments _____

Number of floors _____

Description of building ______________________________

____

____

____

____

Mixed use buildings (record % and description)

% residential _____

% commercial _____

% government _____

OOS Reasons

NATIONAL SURVEY OF BUILDING MATERIAL

Advance Form

Commercial Building Sample

Building ID#: ______________________

Building name: ______________________

Building address: ______________________

____

____

(if vague address) establishment name: ______________________
(fill in address above)

Constructed before Jan. 1, 1979? |__| yes |__| no (OOS)

50% or more commercial? |__| yes |__| no (OOS)

List up to 10 establishments

list outside addresses

Verify zip code from establishment mailing address: ______________
Zip Code

total number of establishments: ______________
number of floors: ______________

Describe building:

Mixed use buildings (record % and description)

_______% residential:

_______% government:

_______% commercial:

OOS reason:

NATIONAL SURVEY OF BUILDING MATERIALS

BUILDING SUMMARY SHEET

Building ID: ______________________ Inspection Date: __________

Building Name: ______________________ Inspection Team: __________

Building Address: ______________________

____

Contact Name ______________________

Title ______________________

Telephone ______________

Year of Construction: ______________

SUMMARY DATA:

floors (include basement) __________

maps __________

sampled areas __________

fan/boiler rooms __________

samples taken __________

Q.A. samples taken __________

total square feet of building __________

Type of Construction (check one)

- frame ○
- masonry ○
- steel beam ○
- other ○

Use (check one)

- office ○
- commercial ○
- residential ○
- mixed (specify) ○ __________

COMMENTS: (include comments about major alterations, renovations and additions)

Portion of building not inspected (in sq. ft.): __________ Reason: __________

____

____

Building ID ____________________

Building Name ____________________

Form A. Friable Material Areas (ceiling, walls, other) and Ceiling Tile Area Samples Outside Fan/Boiler Rooms

(take only convenience sample of ceiling tile)

Map #	floor # room # apt.# etc.	Area #	Location: ceiling, wall, ceiling tile, other	Total square feet	Exposed Yes (1) No (2)	Type of material: 1 - fibrous 2 - granular cementicious 3 - concrete-like	Condition Code 1 – 5 (1) = Best (5) = Worst	Selection (1) Plot (2) Conv	Random ID Sticker*

*Bracket each pair of side-by-side samples

Building ID ____________

Building Name ____________

Form B. Floor Tile and Pipe Wrap Convenience Samples Outside Fan/Boiler Rooms

(one sample per area, plus Q. A. samples when taken)

TILE

Map #	Floor # Room # Apartment # etc.	Area #	Total Square Feet	Random ID Sticker*

PIPE WRAP

Area #	Floor # Room # Apartment # etc.	Describe Pipe or Duct	Condition Code: 1 – 5 (1) = Best (5) = Worst	Random ID Sticker*

*Bracket each pair of side-by-side samples

Building ID ____________________

Building Name ____________________

Form C. Fan/Boiler Room Samples

Number of fan/boiler rooms ________________

Fan/Boiler Room Location in Building Floor #	Area #	Location of Material Ceiling, Wall Other (pipe wrap, boiler insulation, duct insulation, describe)	Condition Code 1 – 5 (1) = Best (5) = Worst	Random ID Sticker*

Bracket each pair of side-by-side samples

Exterior Map

Map # ________ Bldg. ID ________ Bldg name ________

SKETCH EXTERIOR SHAPES WITH DIMENSIONS

Square Feet Shape I (show calculations)

X number of floors = TOTAL ________

Shape II

X number of floors = TOTAL ________

Shape III (Record additional shapes on back)

X number of floors = TOTAL ________

Total square feet of building (sum shapes) (include basement)

________ + ________ + ________ = ________

TOTAL SQUARE FEET

Sampling Area Map

Map # ________ Area # ________ Bldg ID ________ Bldg name ________________

Location ______________________________ Floor # ________

SKETCH AREA WITH DIMENSIONS
MARK SAMPLES WITH X

Total square feet of area:

RN ________ X ht ________ = ________________
RN ________ X width ________ = ________________

RN ________ X ht ________ = ________________
RN ________ X width ________ = ________________

RN ________ X ht ________ = ________________
RN ________ X width ________ = ________________

IF CONVENIENCE SAMPLE, RECORD REASON

Repeat on back for additional samples

Building ID: ____________________________ # Maps ______________

Building Name: __________________________ # Data Form A________

B________

C________

Residential Forms ________

Edit Check List

I |_| Check all items on summary sheet are complete and accurate.

|_| Check building ID on all pages.

|_| Be sure that all maps are numbered sequentially and that there is an exterior map and a map for each sample listed on Form A and for floor tile on Form B.

II Exterior Map

|_| Check to see that diagram is understandable and that all exterior dimensions are clearly marked.

|_| Check to see that number of floors is clearly marked and includes basement.

|_| Check to see that total square feet calculation is clear and accurate.

III S.A. Maps

|_| Check to see that all information on top of page is filled out.

|_| Check to see that area location is as specific as possible.

|_| Check to see that random coordinate calculations are clear and that the samples are clearly marked with an X.

|_| Check to see that the square feet calculation is clear and accurate.

IV Data Forms

|_| Check all columns on all data forms. Be sure that Q.A. samples are bracketed.

|_| Be sure that the specific place where the sample was taken is recorded so that the sample spot may be identified to the building owner by room number, floor number, etc.

|_| Be sure that all information from the maps agrees with the information on the data forms.

REQUEST FOR REPORTS

Building ID: ______________

Building Name: ____

Building Address: ____

____

____

Owner's Name: ____

Title: ____

Telephone #: ________________________

Mailing Address of Owner: ___________________________________

____

____

Type of Report:

1. Lab results of samples taken.
2. Final Report of survey.
3. Other (Specify) ______________________________________

____

____

____

____

____

____

SURVEY OF PUBLIC BUILDINGS

Residential Building Data Form

Building ID: __________ Page 1 of ___

Building name: ____

I. Building is: a single building |__| (go to III) (Check one)

part of a complex |__| (go to II).

II. Boiler room information for a building in a complex.

A. Every building in the complex has its own boiler room:

Yes |__| (go to III)

No |__| (go to B)

B. There are no boiler rooms in any building in the complex.

Yes |__| (go to III)

No |__| (go to C)

C. Boiler rooms in one building of the complex serve other buildings in the complex.

Yes |__| (fill in data below)

No |__| (go to D)

Name of building housing boiler room that serves sampled building:

____

List all buildings served by this boiler room: ______________

____

____

____

D. None of A, B, or C. Use this space and back to describe the situation.

____

Residential Building Data Form (Continued)

Building ID: __________ Page ___ of ___

Building name: ____

Section _____ of _____.

Describe location of section: ______________________________

____

____

III. Floors selected:

A. Number of floors with apartments: __________

Five or fewer |__| (go to IV)

More than five |__| (go to B)

B. Designate sample floors (Attach Worksheet)

__________, __________, __________, __________, __________

IV. Apartments selected: (Attach Worksheet)

Floor	Apt. #	Floor	Apt. #

The apartments selected were inspected:

Yes |__| (end of data form)

No |__| (go to V)

Residential Building Data Form (Continued)

Building ID: __________ Page ___ of ___

Building name: ____

V. Apartments inspected:

Floor	Apt. #	Replaces Apt. #	Comments

Comments: *(Information about additions, alterations, renovations, or lack thereof is especially relevant to a judgment of the likely "representativeness of a given apartment.)* ______________________________

Worksheet for Sampling Five Floors

Building ID: __________ Page ___ of ___

Building name: ______________________________

Number of floors containing apartments: _________

1. Random number: __________ = Floor #: __________
2. Random number: __________ = Floor #: __________
3. Random number: __________ = Floor #: __________
4. Random number: __________ = Floor #: __________
5. Random number: __________ = Floor #: __________

Line #	Floor #	Line #	Floor #	Line #	Floor #
1		1		1	
2		2		2	
3		3		3	
4		4		4	
5		5		5	
6		6		6	
7		7		7	
8		8		8	
9		9		9	
0		0		0	
1		1		1	
2		2		2	
3		3		3	
4		4		4	
5		5		5	
6		6		6	
7		7		7	
8		8		8	
9		9		9	
0		0		0	

Worksheet for Sampling Two Apartments on One Floor

Building ID: __________

Building name: ____

Floor: __________

Number of apartments on floor: __________

Line #	Apt. #	Line #	Apt. #	Line #	Apt. #
1		21		41	
2		22		42	
3		23		43	
4		24		44	
5		25		45	
6		26		46	
7		27		47	
8		28		48	
9		29		49	
10		30		50	
11		31		51	
12		32		52	
13		33		53	
14		34		54	
15		35		55	
16		36		56	
17		37		57	
18		38		58	
19		39		59	
20		40		60	

Random number = __________, Apt. # = __________

Random number = __________, Apt. # = __________

NATIONAL SURVEY OF ASBESTOS IN BUILDINGS

LABORATORY ANALYSIS DATA FORM

LABORATORY OFFICE USE ONLY:
NOTEBOOK #:_____ PAGE #:_____
DATE ANALYZED:________ ANALYST:_____

SAMPLE ID#: 7901-17-________ FIELD ID#:______________

SAMPLE DESCRIPTION:____

ASBESTOS FOUND?: _____NONE DETECTED _____TRACE _____GREATER THAN 1%

PLEASE COMPLETE FOR ALL ITEMS. ENTER "NONE DETECTED" IF NONE FOUND.

MATERIAL	PERCENT	IF A RANGE, SPECIFY HERE.
ASBESTOS:		
CHRYSOTILE	_____	_____ - _____
AMOSITE	_____	_____ - _____
OTHER ASBESTOS	_____	_____ - _____
SPECIFY OTHER TYPE(S) OF ASBESTOS:__________		
FIBROUS NON-ASBESTOS:		
GLASS WOOL OR MINERAL WOOL	_____	_____ - _____
FIBERGLASS	_____	_____ - _____
CELLULOSE	_____	_____ - _____
OTHER FIBROUS NON-ASBESTOS MATERIALS	_____	_____ - _____
SPECIFY OTHER TYPE(S) OF FIBROUS NON-ASBESTOS:__________		
NON-FIBROUS NON-ASBESTOS:		
PERLITE	_____	_____ - _____
VERMICULITE	_____	_____ - _____
OTHER NON-FIBROUS NON-ASBESTOS MATERIALS	_____	_____ - _____
SPECIFY OTHER TYPE(S) OF NON-FIBROUS NON-ASBESTOS:__________		

OFFICE USE ONLY
BUILDING NAME:______________________________
LOCATION SAMPLE TAKEN:______________________________

APPENDIX C

PLM PROTOCOL

ANALYSIS OF BULK SAMPLES
FOR ASBESTOS AND/OR OTHER MATERIALS

I. Microscopic Analyses

CAUTION: Perform all asbestos analyses in laboratory fume hoods.

This protocol conforms to that given in the EPA Interim Method for the Determination of Asbestos in Bulk Insulation Samples[1] and as amended in the Federal Register.[2,3] Quantitation was obtained by observing the entire sample through the stereomicroscope and visually estimating the percentage of each component relative to the whole sample. The results are comparable to those obtained by the 400-point count quantitation method described in the Interim Method.[1,2,3] Asbestos-containing samples with known quantities of asbestos serve as guides for maintaining the accuracy of the estimates. Visual estimation of quantity, with the aid of a stereomicroscope, is commonly used by laboratories during asbestos analyses.

A. General and Stereomicroscopic Observations

1. Empty the entire bulk sample onto clean weighing paper. Describe general appearance in laboratory notebook (e.g., floor tile, acoustical tile, etc.).

2. Examine the sample under the stereomicroscope at 7 to 30x magnification. Use tweezers and probes to expose all

materials to view. Write stereomicroscopic observations in laboratory notebook.

B. Polarized Light Microscope (PLM) Observations

All fibrous components in bulk sample must be identified, although nonasbestos fibers may be designated by class only (e.g., synthetics). The PLM procedures in Step 4 below may be performed in any order.

1. Set up the PLM for Kohler illumination in a manner similar to that described by McCrone (McCrone, W. C., et al., Polarized Light Microscopy, Ann Arbor Science, Ann Arbor, Michigan, 1979). Use only steps appropriate for specific PLM and associated illuminator used (e.g., all PLM's do not have a Bertrand lens, all illuminators are not equipped with diffusers).

2. Using tweezers and the stereomicroscope if needed, place representative examples of each type of material present onto a microscope slide and mount them in one or more drops of 1.550 HD and other appropriate index of refraction liquids for PLM analysis. Separate fibers in the liquid, if necessary, then add coverslip.

3. Place prepared slide on PLM stage and focus on sample.

4. Identify asbestiform minerals and other bulk sample components using prescribed polarized light microscope techniques. These techniques include but are not limited to:

(a) Crossed polars (+) - insert upper analyzer and cross the polars. Rotate stage and observe angle of extinction of anisotropic minerals. Observe morphology of fibers.

(b) Slightly uncrossed polars (X).

Optional: May help in determining glass.

(c) Crossed polars plus first order red plate (+Rl): Insert upper analyzer and cross the polars. Insert first order red plate. Rotate stage and observe sign of elongation. Note: First order red plate need be removed only when upper analyzer is in place.

(d) Dispersion staining central stop (CS) or anular stop (AS). Uncross polars and remove upper analyzer. Insert Bertrand lens and rotate central or annular stop into place. Remove Bertrand lens and refocus microscope. Rotate the stage and determine dispersion staining colors of sample materials. Enter in lab book.

(e) Transmitted light (l). (Used when crocidolite is suspected.) Insert Bertrand lens and remove dispersion staining stop from field of view. Remove upper analyzer. Rotate stage and determine pleochroism of suspect fiber(s). Note all PLM observations in laboratory notebook.

C. Estimation of Sample Components

Using PLM results (specific materials identification) combined with carbonate/noncarbonate binder determination and whole-sample observation under the stereomicroscope, estimate volume percentages of all materials and enter in lab book. Standards containing known percentages of asbestos are available for reference.

D. Disposition of Analyzed Samples

1. Return bulk sample to its original primary container and reseal.

2. Damp-wipe the outside of the container and remove sample from hood.

3. If asbestos was found, place "cancer hazard" or other type of carcinogen sticker on outside of primary container.

4. Place analyzed sample in designated secondary container to await storage or other disposition as directed by project/task leader.

E. Handling Discrepancies

If blind analysis by a second MRI analyst or by outside QA contractor produces serious discrepancy, the sample will be compared with standards containing known percentages of asbestos. These standards are available for reference, should they be needed by the analyst to compare with any sample being analyzed.

II. Detection and Quantification Limits

The limits of detection and quantification of asbestos in bulk sample are a function of the presence of materials that tend to coat or otherwise obscure the fiber. In the absence of interferences, detection and quantification limits are simply related to the quantity of sample examined and are well below one percent. Estimated quantification values are relatively accurate under these conditions.

When obscuring materials (e.g., gypsum, calcium carbonate, cement) are present the limits can be greatly increased and may approach or exceed one percent. Special treatments to visualize the asbestos may then be required, such as treatments to dissolve the obscuring materials.

III. MRI Internal QC

An additional 10 percent of the bulk samples will be reanalyzed by a second MRI analyst. Every tenth sample analyzed by the primary analyst will be recoded and analyzed blind by a second person. Results will be compared after the second analysis is complete. Comparison of results may be on a sample by sample basis, or after several of the internal QC samples have been analyzed.

QC analyses will be recorded in a laboratory notebook reserved for this purpose only. The MRI task leader will examine the QC analysis notebook on a regular basis.

REFERENCES:

[1] USEPA. 1982. U.S. Environmental Protection Agency. Environmental Systems Laboratory. Interim Method for Determination of Asbestos in Bulk Insulation Samples. Research Triangle Park, N.C. EPA 600/M4-82-020.

[2] Asbestos; Friable Asbestos-Containing Materials in Schools; Identification and Notification, Appendix A. Final Rule, Environmental Protection Agency, 40 CFR Part 763, Federal Register Vol. 47, No. 103, 23360, May 27, 1982.

[3] Asbestos; Friable Asbestos-Containing Materials in Schools; Identification and Notification; Correction. 40 CFR Part 763, Federal Register Vol. 47, No. 170,38535, September 1, 1982.

APPENDIX D

TRAINING AGENDA

NATIONAL SURVEY OF BUILDING MATERIALS
TRAINING AGENDA FOR ADVANCE PERSON

Date	Time	Topic
September 7	9:00 - 9:30	Overview of advance person's role and tasks
	9:30 - 10:30	Review of general listing procedures, specific procedures and definitions for study
	10:30 - 12:00	Sampling residential subcomplexes and buildings
	12:00 - 1:00	LUNCH
	1:00 - 1:30	Government sample
	1:30 - 2:30	Commercial sample
	2:30 - 3:00	OOS and refusal substitution
	3:00 - 5:30	Reporting and administrative procedures

NATIONAL SURVEY OF BUILDING MATERIALS

Date	Time	Topic
September 8	9:00 - 9:30	Introduction to study and background on asbestos
	9:30 - 10:00	Schedule travel, advance work reporting
	10:00 - 12:00	The building inspection, identifying materials and areas to be sampled, sample collection, importance of data forms
	12:00 - 1:30	LUNCH
	1:30 - 3:30	Field contact, route, cooperation Roles of team Data forms, procedures
	3:30 - 4:30	Sample recording, Q.A. samples
	4:30 - 5:30	Residential sampling
September 9	9:00 - 10:30	Exterior maps
	10:30 - 12:00	SA maps and random selection proceduraes
	12:00 - 1:00	LUNCH
	1:00 - 3:00	Exercise using library as building -- all forms and folders and edit check, exercise, transparencies
	3:00 - 4:00	Mailing to lab and Westat
	4:00 - 5:00	Sign out materials, answer questions, final comment E.P.A.

APPENDIX E

SAMPLE DESIGN
AND
EVALUATION OF FRAMES

SAMPLE DESIGN

I. OVERVIEW OF DESIGN

The survey employs a multi-stage stratified design to sample buildings to be examined for the presence of asbestos-containing materials. As shown below, there are three types of buildings (strata) to be selected, with a total target sample size of 224 buildings. They are:

Private Nonresidential Buildings	112
Private Residential Buildings with 10 or more Units	56
Federal Government Owned and Leased Buildings	56
	224

Public school buildings are not considered in this design, as asbestos in schools is a separate program area. Other exclusions for program reasons are vacant buildings, buildings used primarily for storage such as warehouses, buildings owned or leased by the military, buildings used in agriculture, and privately-owned homes and apartments. Buildings owned or leased by state and local governments are excluded because the additional expense involved in listing such buildings was deemed too great. Also, they can be assumed to share many characteristics with Federal government and commercial office space.

For the purposes of the survey a building has been defined as:

(1) A free-standing structure;

(2) Part of a contiguous building with distinct architecture;

(3) A separately-owned continguous building with the same architecture; and/or

(4) For a contiguous building with the same architecture and the same owner, if divided by a permanent interior wall (for residential buildings this is assumed to be equivalent to having distinct street addresses).

The sample of buildings was drawn using a multi-stage stratified design. In the first stage an area sample of the U.S. was drawn with probability proportional to 1980 population size. Within each of these areas or primary sample units (PSU's), a stratified list sample of buildings was drawn. For private nonresidential and residential buildings an additional intermediate sampling stage was used to reduce the task of listing all the buildings within the PSU's.

II. FIRST STAGE: SAMPLE OF PSU'S

The first stage in sample selection was selecting a sample of ten areas, known as Primary Sampling Units (PSU's), to represent the continental United States. This selection proceeded as follows. The continental U.S. consists of over 3,000 counties and independent cities. These were grouped into approximately 1,000 PSU's, following the grouping used by the Census Bureau in its Current Population Survey and other work. Urban counties are grouped into Standard Metropolitan Statistical Areas (SMSA's), and rural counties are grouped into PSU's of a minimum total population. The PSU's were then placed in ten strata: large SMSA's by Census Region* (4 strata), medium and small SMSA's by Census Region (4 strata), rural PSU's in the South Region, and rural PSU's in all other Regions. In each

*The four Census Regions are: North East, North Central, South and West.

stratum, PSU's were sorted by such factors as ethnic and income distribution, and one PSU was chosen with probability proportional to 1980 population to represent each stratum. The first-stage probability of selection, denoted pi for PSU i, is thus equal to:

$$pi = \frac{\text{population, PSU i}}{\text{total population, stratum i}}$$

III. SECOND STAGE SAMPLING WITHIN PSU's

A. Private Nonresidential Buildings

A middle stage of sampling was introduced--selection of post office ZIP codes within PSU--to reduce the amount as well as cost of building enumeration. Four ZIPs were drawn from each PSU, as this number was sufficient to produce the desired number of buildings.

All nonmilitary ZIP codes were listed as recorded by the post office. Each ZIP code was assigned a measure of size equal to the square root of the number of employees in that ZIP code, which was derived from the 1980 County Business Patterns. Four ZIPs were then selected with probability proportional to size using a stratified systematic sample. Since the number of employees is highly correlated with the number of buildings, this was thought to be a good measure of size. The square root of this number was used so that the largest ZIP codes would not excessively dominate the sample.

ZIP codes were ordered sequentially within each PSU. Since the target sample for a PSU was four ZIP codes the skip interval was set equal to the total measure of size divided by four. Certainty ZIPs were identified as those with individual measure of size greater than the skip interval for that PSU. Non-certainty ZIPs were chosen by applying the skip interval independently by PSU. Define:

> z_{ij} as the selection probability for ZIP j within PSU i.

This is equal to the measure of size for the selected ZIP divided by the skip interval. For certainty ZIPs $z_{ij}=1$.

B. Private Residential

Here the intermediate stage was a list sample of Census Blocks containing buildings with 10 or more housing units. Census Blocks were delineated for each PSU according to the 1980 Census Summary Tape Files No. 1B. Where there were no blocks, enumeration districts (ED's) were used instead (this occurred in rural areas). Twelve blocks were selected from each PSU, again, because this number was expected to be sufficient to produce the targeted sample size.

Blocks were assigned a measure of size equal to the square root of the number of units in buildings with 10 or more units. The square root of this measure was used so that blocks with a large number of 10+ residential buildings would not dominate the sample. In instances where there was at least 1 but less than 10 of these units (a physical impossibility but a reporting reality), the block was assigned a measure of size equal to 2.

Blocks were sorted by their unique Census ID number (state no./tract no./block(ED) no.) within PSU and sampled systematically with probability proportional to size. A skip interval was calculated equal to the total measure of size for that PSU divided by 12, the target sample size. Certainty blocks were identified as those with individual measure of size greater than the skip interval for that PSU. Noncertainty blocks were chosen by applying the skip interval to each PSU independently.

Let b_{ij} be the within-PSU block selection probability for block j within PSU i. This was equal to the measure of size for the selected block divided by the skip interval.

IV. BUILDING FRAMES

After intermediate stage sampling, building frames were developed separately for each building type but each was sampled in the same manner. Buildings were assigned to size class strata based upon their square footage. A stratified systematic sample was drawn to achieve the targeted sample sizes for each PSU. Where necessary, adjacent size strata were collapsed independently for each PSU and building type.

A. Private Nonresidential Buildings

A list of buildings within each sampled zip was enumerated by using establishments provided by Dun & Bradstreet in combination with National Business Lists. Both sources are comprised of business establishments but are created from different sources and have differing coverage of various types of businesses. Dun & Bradstreet, which was treated as the main list, is based on credit references, while NBL is derived from businesses listed in the phone book.

These establishment lists were manually studied and reduced to building lists by selecting only one establishment per unique address. All addresses associated with agricultural businesses and those establishments from NBL designating private and public schools (except post-secondary) and government and apartment buildings were deleted.

B. Private Residential

Field workers enumerated all residential buildings with 10 or more rental units that were situated within the sampled census blocks (or ED's). The total number of units within each building was identified, where the building was defined according to the definition detailed above. The building frame was then constructed by listing all the building complexes and assigning a measure of size to each based on number of apartments. Buildings which were not part of a complex were listed individually with individual measures of size.

C. Government

Building records from the General Services Administration's (GSA's) owned and leased Real Property Inventory (1979) were used to create a list of federally owned and leased buildings. Military and Army Corps of Engineers buildings as well as warehouses and buildings with 0 square feet were not included. Each record represented a building or group of buildings with the same usage type at a particular installation of a Federal department or agency.

V. BUILDING SAMPLE

All buildings were classified by square footage into size strata. These were as follows:

Size Class	Square Feet
1	1-1000
2	1,001-5,000
3	5,001-10,000
4	10,001-25,000
5	25,001-100,000
6	100,001+

Square footage was provided by the GSA for each government building or facility but for the other building types square footage had to be estimated:

A. Private nonresidential buildings "composed" of D&B establishments had available the total number of employees for all the establishments as reported by D&B. The number of employees was converted to square feet based upon the two-digit Standard Industrial Classification (SIC) code of the largest employer at that address. This conversion factor ranged from 305 square feet per employee for restaurants to 1,290 for education.

B. Buildings "composed" solely of NBL establishments were assigned to size class 3, since NBL, based strictly upon telephone book listings, did not have any size information available.

C. Buildings composed of both DMI and NBL establishments followed the procedure in (A).

D. Residential buildings were assigned to a size class by using a conversion factor of 1000 square feet per housing unit.

A stratified systematic sample was drawn from the building frame in each PSU. Sampling rates were chosen so that two criteria were satisfied: (1) Sample sizes were achieved as outlined below for each building type within a PSU:

Building Stratum	PSU Sample Size
Federal government	6
Residential	6
Private non-residential	11

and (2) relative overall sampling rates for size strata were fixed according to the sampling plan:

Size Class	Sampling Rate
1	R/20
2	R/10
3	R/5
4	R/4
5	R/2
6	R

These relative rates had been calculated so that the overall probability of selection was in proportion to the square root of the average building square footage for a size class stratum.

Let w_{hijk} be the within strata sampling rate for frame h, PSU i, intermediate segment j, and size class k. This intermediate segment was the zip code for private nonresidential buildings, the census block (ED) for private residential buildings, and it did not exist for government buildings (i.e., $w_{hijk} = w_{hik}$, for all j).

Where low levels of PSU selection probability and segment probability necessitated sampling more than 100 percent of the buildings, the overall sampling rate could not be achieved. In these instances all buildings within that size class were identified as certainty buildings and selected with rate w_{hijk} equal to 1.

The building sample was drawn independently by type and PSU, using a skip interval of $1/w_{hijk}$ after a random start. Where expected sampling sizes revealed that no unit at all might be drawn from a particular stratum, it was collapsed with an adjacent stratum (or strata) and the relative overall sampling rate recalculated.

Before sampling, buildings were sorted in the following orders:

A. Private nonresidential -- By PSU, zip code, size class, and four-digit SIC code.

B. Private residential -- By PSU, state, tract, census block (ED), size class, building complex, and square footage.

C. Federal -- By PSU, size class, owned/leased, and usage type.

Refusal Substitutes

Substitute units were necessary as a backup in case of respondent refusal. They were selected by choosing the next record in the building frame directly following the sampled unit, with these provisions:

(1) The backup building remained within the same size class as the sampled building; and

(2) For private residential and government buildings, the backup was not within the same complex or facility (to preclude selecting the same respondent twice).

Out-of-Scope Substitutes

Substitute units were also necessary when the sampled unit was determined to be out-of-scope during field investigations. These were drawn from the PSU lists in the same way the original sample was drawn, as needed. A substitute was not necessarily within the same size class as the unit it replaced.

Subsampling

Certain Federal government and private nonresidential records selected in the previous stage were identified as groups of buildings from which a subsample had to be drawn. For private nonresidential units, field investigation sometimes determined that a sampled address actually represented several buildings, which were then also subsampled.

A subsample was drawn by stratifying each building in a given complex on the basis of its square footage, and assigning it a measure of size:

m_1 = relative sampling rate of size class 1 of the building for that PSU and segment.

The probability of selection for each building is given by

$$ss_1 = m_1/\Sigma m_1$$

where the denominator is the sum of m_l over all buildings in the complex. This subsampling method selects one building per complex with probability proportional to building size.

The final selection probability for a sampled building is:

$f_{ijkl} =$

$p_i \times z_{ij} \times w_{hijk} \times ss_l$, for private nonresidential buildings

$p_i \times b_{ij} \times w_{hijk} \times ss_l$, for private residential buildings, and

$p_i \times w_{hik} \times ss_l$, for government buildings.

Thus, each sampled unit represents $1/f_{ijkl}$ similar units in the building universe.

EVALUATION OF FRAMES

I. FEDERAL GOVERNMENT

The GSA RPI list is very complete. We had great confidence in the coverage provided by this frame. Two aspects of the frame caused some operational difficulty. One was the large amount of ineligible buildings on the list and the other was the multiple-building feature of some records. This feature meant that we could not simultaneously control the sample size and the probability of selection for each building. We chose to control the sample size.

The proportion of ineligible buildings on the frame is summarized in Table E-1. In our initial sample of building records, about 25 percent of the records proved ineligible for our study, for a variety of reasons summarized in the table. Operationally this posed some problems in terms of additional contacts required to obtain the desired sample size. Also, there is no alternate data source for estimating the total number of Federal government buildings in our target universe, so our estimate of that total is based on the sample weights for the 66 inspected buildings.

II. PRIVATE NONRESIDENTIAL BUILDINGS

Although we have no firm figures, we believe that the combined list frame for these buildings provides good but not perfect coverage of the target universe. Areas of weakness would be buildings whose occupants do not seek credit references or advertise in the Yellow Pages.

Table E-1. Eligibility rates and reasons for ineligibility in initial sample, Federal government buildings (unweighted)

Area	Eligibility rate in initial sample
1	83%
2	50%
3	50%
4	83%
5	100%
6	50%
7	67%
8	67%
9	50%
10	100%
Total	73% (n=66 initially sampled buildings)

Reasons for ineligibility	Percent of ineligible buildings
1. Less than 50 percent of building occupied by Federal government	41%
2. No longer leased	24%
3. Not a building (radar, beacon, etc.)	24%
4. Ineligible building (garage, storage, warehouse, vacant)	12%
	(n=18 ineligible buildings)

The major design problem caused by the form of the list was that it consisted of addresses, whereas our target universe was buildings. Thus, we could not completely control both sample size and probability of selection. Again we chose to control sample size and had to adjust the sampling weights for multiple address buldings. In some cases we also found multiple buildings at one address, where the address was for a "compound" covering a city block. In these cases we selected only one building for the study, again disrupting the sampling probablities.

Also, this frame contained even more ineligibility than the Federal government frame, as shown in Table E-2. The overall eligibility rate in the initial sample was just over 60 percent. Over half the ineligibles were buildings which were less than 50 percent commercial. These were either businesses being run out of private homes (from the Yellow Pages list) or businesses on the first floor of a building which had apartments on the second and higher floors. As in the Federal government sample, this caused extra advance work to find a sufficient sample of eligible buildings. However, for this stratum of the target universe there does exist an alternative means of estimating the total number of buildings, the Department of Energy 1981 Nonresidential Building Energy Consumption Survey. Thus, the high level of ineligibility in the frame did not add sampling variance to the estimates of total buildings in this stratum.

III. RESIDENTIAL BUILDINGS

Since the residential building frame was constructed by field observation, there was much less chance for a mismatch between sampling frame entry and eligible building. Thus, we have the most confidence in this frame. However, the problem of estimating a universe total occurs for this stratum since the

Table E-2. Eligibility rates and reasons for ineligibility, in initial sample, private nonresidential buildings

Area	Eligibility rate in initial sample
1	18%
2	100%
3	73%
4	73%
5	73%
6	55%
7	36%
8	64%
9	55%
10	73%
Total	62% (n=114 initially sampled buildings)

Reasons for ineligibility	Percent of ineligible buildings
1. Less than 50 percent of building occupied by business (usually business in private home)	60%
2. Built after January 1, 1979	14%
3. Ineligible building (storage, garage, warehouse, vacant, closed)	14%
4. Located in nonsampled ZIP code	12%
	(n=43 ineligible buildings)

frame-building approach did not generate national counts of numbers of 10-plus rental unit apartment buildings. Independent estimates are again not available, so our estimate of this total is based on the sampling weights of the 55 inspected residential buildings.

APPENDIX F

CALCULATING WEIGHTS AND VARIANCES

APPENDIX F

CALCULATING WEIGHTS AND VARIANCES

1. Calculation of Preliminary Base Weights

Preliminary base weights were calculated for each inspected building. Adjustments to these weights were made for both nonresponse and out-of-scope substitutions. The manner of adjustment varied between the pilot site and the remaining PSUs as well as among the three building lists (government, residential and commercial).

Initial Sampling Probability

Every sampled building on the three lists was assigned an initial selection probability of

$$P_{hijkl} = PSU_i seg_j sclass_{hijk} sub_l,$$

where

PSU_i	is the selection probability of PSU i;
seg_j	is the selection probability of either a ZIP code for commercial listings or a census block for residential listings;
$sclass_{hijk}$	is the selection probability of a unit in size class k, which is unique for list h, PSU i, and segment j; and
sub_l	is the subsampling rate for unit l where the originally sampled unit represented a complex of buildings.*

The preliminary base weight is then $w_{hijkl} = 1/P_{hijkl}$.

*Subsampling rates were included here for residential buildings only; for government and private nonresidential buildings, subsampling rates were applied later, after first adjusting for ineligible listings--see Section 4.

2. Adjustments to Base Weight - Ineligibility and Nonresponse

a. Private Nonresidential Buildings

Adjustments to the base weight were made by PSU and size class to reflect the number of originally sampled listings which were out-of-scope for the study. In addition, the weights were adjusted to agree with the total number of listed addresses in each ZIP code from which the sample was drawn. This last measure helped correct for the inaccuracy of within-segment sampling rates imposed by small sample sizes.

Let n_{ijk} and n'_{ijk} be the number of originally sampled and eligible listings, respectively, in PSU i, segment j and size class k. Then

$$e_{ik} = \frac{\sum_j n'_{ijk} / seg_j}{\sum_j n_{ijk} / seg_j}$$

is the estimated percentage of eligible listings in PSU i and size class k.

Let N_{ijk} be the number of address listings in PSU i, segment j and size class k, and n''_{ijk} be the number of inspected listings. Then,

$$adj_{ik} = \frac{\sum_j N_{ijk} / seg_j}{\sum_j n''_{ijk} / (seg_j \times sclass_{hijk})}$$

adjusts the inspected listings in PSU i and size class k so that their weights sum to the total number of listings in each ZIP code. The final adjusted base weight then becomes

$$w'_{hijkl} = w_{hijkl} \times e_{ik} \times adj_{ik}.$$

There were no units for which substitutes could not be found; hence, no adjustment for nonresponse was needed.

b. Government Buildings

The adjustment for ineligibles followed the same procedure adopted for private nonresidential buildings, except adjustments were made across PSUs by size class, separately for the pilot site and the remaining PSUs. Since no segments were used in this sample, the formulas differ as follows:

$$e_k = \frac{\sum_i n'_{ik} / PSU_i}{\sum_i n_{ik} / PSU_i} ,$$

$$adj_k = \frac{\sum_i N_i / PSU_i}{\sum_i n''_{ik} / (PSU_i \times sclass_{hijk})} ,$$

and $w'_{hijkl} = w_{hijkl} \times e_k \times adj_k$

Again, no adjustment for nonresponse was needed.

c. Residential Buildings

Residential buildings were adjusted for nonresponse and ineligibility with one adjustment by PSU and size class:

$$adj_{ik} = \frac{\sum_j w_{hijk}\ (1)}{\sum_j w_{hijk}\ (2)}$$

where the numerator is the sum of the preliminary base weights for originally sampled eligible units and the denominator is the same sum for finally inspected units.

Then $w'_{hijkl} = w_{hijkl} \times adj_{ik}$

3. Adjustments to Base Weight - Within-List Multiple-Selection Probability

a. Private Nonresidential Buildings

The sampled units for the private-nonresidential frame were actually unique addresses or, in the case of vague address (e.g., 4th and Main Sts.), unique establishment names.

In the first case, the building examined may have had several chances of being selected if there was more than one address at its location. The advance field forms identified these other addresses (and establishments) within the building. The sampling frame was evaluated to determine if these other addresses were listed.

Let w' be the adjusted base weight of the original address. Let w'_1, w'_2, ... w'_n be the adjusted base weights which would have been assigned to the n other addresses located at the inspected building and listed on the frame. Then the base weight adjusted for multiple probability of selection becomes

$$w'' = w' + \sum_{i=1}^{n} w'_i$$

For the case in which a building with a vague address had multiple establishments, each with a vague or specific address listed on the sampling frame, this building also had a multiple probability of selection and was adjusted in the same manner as above.

For all buildings with no within-list adjustment define $w'' = w'$. Note that we have made this adjustment after that in Section 2 because some buildings were comprised of listings in several size classes; the previous adjustments were within-size class.

b. Government Buildings

A sampled building may have had several chances of being selected if there was more than one lease listed for the same location. In that case the building was adjusted for multiple probability of selection as in Section 2(a) above, otherwise $w'' = w'$.

c. Residential Buildings

Since these were listed in the field, there was no chance of multiple listings per building; hence, no adjustment was necessary.

4. Adjustments to Base Weight-Subsampling

Private nonresidential and government buildings which were subsampled were adjusted as follows:

$$w'''_{hijkl} = w''_{hijkl} / sub_l .$$

The subsampling rate was applied after the adjustments in Section 2 because these previous adjustments were alterations to the selection probability of the listing. This final adjustment creates the selection probability of the building.

For buildings which were not subsampled, define $w'''_{hijkl} = w''_{hijk}$.

5. Final Weights - Ratio Adjusted

a. Private Nonresidential Buildings

In order to improve the estimate of the number of private nonresidential buildings, the building weights were ratio-adjusted to agree with a more precise estimate.

The Nonresidential Building Energy Consumption Survey, conducted by the Department of Energy in 1979-1980 (the DOE survey), collected data on over 6,000 buildings in the U.S. Any building which showed evidence of commercial or industrial activity was eligible including those which were primarily residential. If these latter buildings are excluded, we can estimate the population with which this study is concerned.* (Those buildings constructed since the DOE survey was conducted were out-of-scope by our definition.)

*Educational, agricultural, storage, and government-owned or occupied buildings were also excluded from the DOE figures.

Estimates of numbers of buildings were calculated for sampling size classes using the DOE file. The adjustment size classes were:

	<u>Square Feet</u>
1.	1 - 10,000
2.	10,001 - 25,000
3.	25,001 - 50,000
4.	50,001+

Define

DOE_k = number of private nonresidential buildings estimated by the DOE survey for adjustment size class k;

then,

$$\text{ratio\_adj}_k = \frac{DOE_k}{\sum_{i=1}^{n_k} w'''_{hijkl}} .$$

where

n_k = the number of sample buildings in adjustment size class k.

Let fw_{hijkl} equal w'''_{hijkl} times ratio_adj_k for all nonresidential buildings. Then, fw is the final adjusted building weight.

b. Government Buildings

The government list sample cannot be adjusted to the total square footage of its frame since many of the government buildings are ineligible, e.g., leased office space housed in private office buildings, poorly identified storage spaces, odd building types (e.g., radar and monuments), and transitions since the year of file creation. However, an adjustment was made to the weights for government buildings to bring the total square footage of the frame for the sampled PSUs in line with the figures for the continental U.S. Buildings could not be adjusted to agree with the total number of buildings per size class since records within a size class often represented complexes of buildings whose individual sizes were unknown.

This ratio adjustment was made by size class as follows:

Owned buildings	Leased buildings
1 - 1,000 sq. ft.	1 - 1,000
1,001 - 25,000	1,001 - 100,000
25,001+	100,001+

Define $ratio\_adj_k$ to be the ratio adjustment for one of the k size classes above. Then

$$fw_{hijkl} = w'''_{hijkl} \times ratio\_adj_k$$

for government buildings.

c. Residential Buildings

The number of 10+ dwelling units was adjusted at the primary stratum level so that the number of units represented in a PSU weighted up to the stratum total for the stratum containing that PSU. Three adjustment strata were defined as PSU 1, PSUs 2-8, and PSUs 9-10. The stratum totals (or universe counts) were derived from the General Housing Characteristics, 1980 Census of Housing, U.S. Summary, May 1983.

Let $ratio\_adj_k$ be the ratio of the stratum total to the weighted PSU total within that stratum. Then

$$fw_{hijkl} = w'''_{hijkl} \times ratio\_adj_k$$

for residential buildings.

6. Variance Estimates

Sampling variances were estimated by the method of balanced repeated replications (BRR). Five variance strata with two PSUs per stratum were created by pairing homogeneous PSUs. Eight half samples were created by considering five columns of an 8 x 8 (0-1) orthogonal matrix. Each of the eight half samples involved a unique combination of one PSU from each of the five strata.

A set of eight half-sample weights was derived for each sampled building. Each half-sample was individually ratio-adjusted in the manner of the full sample as discussed in section F-5. These half-sample weights, with the replicate definitions, allowed variances, standard errors, and 95 percent confidence limits to be calculated for key estimates.

Variances, standard errors, and confidence limits were calculated using the method of Balanced Repeated Replication, presented by McCarthy (1966, 1969).* This method was carried out using NASSVAR, a user-defined PROC written for the data analysis package SAS.

*McCarthy, Philip (1966) "Replication, an Approach to the Analysis of Data from Complex Surveys" Public Health Service Publication No. 1000, Series 2, No. 14.

McCarthy, Philip J. (1969) "Pseudoreplication, Further Evaluation and Application of the Balanced Half-Sample Technique" Public Health Service Publication No. 1000, Series 2, No. 31.

APPENDIX G

QUALITATIVE BUILDING DESCRIPTIONS

TABLE 1. NORTHEASTERN SUBURBAN AREA

Buildings inspected	Surrounding buildings
Brick and masonry, vinyl tile, suspended tile	Single-story commercial and residential
Two-story stone building, terrazzo floor and vinyl tile, spray-in insulation in attic	Two-story brick commercial and residential
Wooden two-story building, vinyl floor cover, recent insulation removal (asbestos) sprayed-on in boiler room, 4 units inspected	Similar wooden structures nearby, a few brick buildings interspersed
Wooden single-story building, vinyl flooring, suspended ceiling, suspect material in furnace room	Wood two-story structure nearby
Two-story brick apartments, vinyl floors plus carpet, each unit has own heater	Similar apartments in complex and newer apartments in surrounding area
Three-story masonry and stone, porous ceiling tiles, suspended ceiling panels, vinyl tile	Similar buildings in area plus brick exterior industrial complex
Brick single-story, vinyl tile, suspended ceiling	Strip commercial-brick and glass stores, residential
Two-story brick apartments, some vinyl tile	Single-family residences, brick, single-story commercial
Two-story converted school, renovated furnace, some vinyl	Single-family wood residences, single-story brick commercial
One-story brick, ceiling tile	Wooden single-family residences, brick school
Single-story masonry and glass stores, vinyl tile, ceiling tile	Brick and wood residential single-story commercial
Single-story brick building converted from boiler house, vinyl tile	Chemical process plant, asbestos concrete type sheeting on building
Renovated service station, vinyl tile, ceiling tile	Residential neighborhood, single-family, wooden

(continued)

TABLE 1 (continued)

Buildings inspected	Surrounding buildings
Single-story brick, vinyl flooring	Strip commercial, steel shell and glass plus residential brick
Single-story masonry, warehouse converted to multiple commercial, new individual heating units	Brick and masonry industrial, single-family wooden residences
Single-story masonry, ceiling tile	Single-family residential plus a few wooden stores
Three-story masonry, ceiling tiles, asbestos concrete type wall covering, vinyl tile	Building adjoining had millboard, asbestos concrete type exterior, other buildings of brick
Brick single-story, space heaters, ceiling tile	Single-family residential brick, single-story commercial
Brick and steel shell building, sprayed-on insulation, suspended ceiling	Single-family residential, single-story brick commercial
Brick single-story, ceiling tile	Similar commercial nearby
Steel shell and glass, suspended ceiling	Similar commercial nearby, also single-family residential
Three-story brick apartment	Other smaller residential units, some brick single-story retail
Single-story masonry, no heat, no sampled materials	Heavy manufacturing in steel-shelled buildings, two-story brick buildings, also smaller brick apartments and wooden residences Five-story apartment, vinyl flooring, textured ceilings
Single-story brick building, ceiling panels, and vinyl floor	Single-story brick and glass commercial plus wooden residential

TABLE 2. MIDWESTERN URBAN AREA

Buildings inspected	Surrounding buildings
Two-story masonry, ceiling tile, vinyl tiles	Brick stores on commercial strip, older residential single-story
Steel shell/insulation blanket	Commercial district, masonry and glass construction
Brick single-story with attached warehouse, OOS ceiling tile, vinyl flooring	Commercial district, relatively new business complex, service and light manufacturing of similar construction
Two-story brick, much piping and pipe insulation, ceiling tiles	Brick, steel, and glass
Apartment house, two-story, 12 units, brick and wood vinyl flooring	New expansion of the city, several more of these complexes in this area; however, these are not typical of city itself
Apartment unit, four stories, brick	Brick and glass two-story, commercial, wooden residential two-story homes, some brick residential
Poured, concrete some vinyl flooring	Masonry and concrete apartment of similar size
$\geq$20-story apartment with commercial on lower floors, sprayed-on material in several areas	Urban renew project of the 1960's, many other units of this type present among original residential flats and strip commercial
Four-story apartment, masonry and wood	Apartment similar to others in area, but two- and three-flat residences predominate
Single-story masonry construction, vinyl flooring, ceiling tile	Typical of stores, two- and three-flat residences predominate
Cinderblock shop, wooden office	Newer construction than surrounding, see above entry
Shop area, metal fabrication, office of brick	Similar to other factories, residential area across street
Multiunit brick apartment complex	Surrounded by similar construction, single-family dwellings in immediate area

(continued)

TABLE 2 (continued)

Buildings inspected	Surrounding buildings
Four-stories, masonry/concrete, vinyl tile, suspended ceiling, sprayed-on insulation in furnace room	Similar to other buildings of this size in area
Seven stories, masonry/concrete, vinyl tile, and ceiling tile	Similar to other buildings of this size in area
Brick veneer, vinyl flooring	Typical of store construction in this area
Masonry two-story large open area with wood block floor	Masonry two-story commercial and residential
Masonry two-story, ceiling tiles, vinyl flooring	Single-story brick commercial and residential
Stucco and wood construction, vinyl tile, and suspended ceilings	Store of the type common in area, single-family residential also
Single-story brick and wood, open structure with arched roof	Similar to other stores in area, masonry/wood construction
Single-story masonry/steel/glass, vinyl flooring	Near multistory brick office, also single-story brick stores in area
Masonry glass and steel, single-story ceiling tile, vinyl flooring	Similar buildings nearby, also smaller size brick store fornts
Masonry/wood, single-story, vinyl flooring, ceiling tile	Conventional construction for this area

TABLE 3. MIDWESTERN URBAN AREA B

Buildings inspected	Surrounding buildings
Four floors, masonry/steel, vinyl floor, sprayed-on acoustical in large area	Commercial district older buildings, smaller size, wood and stone
Two-story, precast concrete/glass, removable floors, vinyl flooring	Similar buildings, others are masonry and steel
Large wooden frame structure, tin roof	Some but not many similar buildings, others metal or masonry
Masonry building, vinyl floor	Strip commercial (smaller stores), single-family residential housing
Masonry/steel building, flat roof	Larger and older stores, steel storage buildings for agricultural products
Nine-story masonry office building with attached garage and landscaped decks, vinyl floors and textured walls	Older facilities of masonry and steel
Brick home converted to office, high-pitched roof	Single-family residences intermixed with single-story commercial masonry structures
Small single-story office, masonry	Similar to other commercial in area, mostly single-family residential
Two-story masonry and steel building, office	Strip commercial in residential area
Masonry, steel, glass store fronts, box construction, vinyl floor, ceiling tiles	Mixed commercial, most in older masonry buildings than selected site except for on geodesic building and high rise office, steel and masonry
Masonry and steel shop/office mix, ceiling tile	Heavy commercial industry, many steel-shell buildings
Brick and wood store front, suspended ceiling	Similar to other commercial, residential use predominant

(continued)

TABLE 3 (continued)

Buildings inspected	Surrounding buildings
Older masonry structure renovated and merged with newer addition	Similar to other commercial in district, also smaller shops and single-family residence in area
Large building, one city block, masonry structure with tall stack, several apartments above offices	Edge of commercial district with single-family homes on other side. Many similar buildings of same vintage, some newer construction also
Masonry structure with much glass, office with large work area and contiguous boiler room	Commercial district, similar building nearby, also steel shell and small stores
Single-story shell, concrete floor	Newer building in area, other structures wood frame and masonry
Masonry and wood structure, garage-type building	Mostly single-family residences, some steel-shell commercial, also a few wooden structures

TABLE 4. SOUTHWESTERN URBAN AREA

Buildings inspected	Surrounding buildings
Large steel and concrete building with open work area and high ceilings, asphalt tile on floor	Urban renewal project replaced single-family wooden housing, some similar buildings near with industry
Masonry building, vinyl floors, heating and A/C on roof	New community of single-story condominiums or private residences
Masonry building, vinyl tile, ceiling tile	Hospital and shops nearby. Post office similar construction to shops
Masonry and steel building used as dormitory	Several similar units nearby
Partially renovated masonry structure linked to two other buildings, brick, concrete, wood	Commercial section with masonry and concrete buildings, also taller steel and glass structure nearby
Two-story apartment units, masonry/steel/stucco	In complex of similar units, neighborhood of strip commercial and single-residence buildings
Two-story apartment units, masonry/steel construction	Near large shopping center and office complex, also in single-family residential section
Two-story masonry apartment units	Near university, among other apartment buildings of same vintage and similar materials
Single-story apartments, masonry/wood construction	Near university, among other apartment buildings of same vintage and similar materials
Two-story apartments, masonry/steel/stucco	Single-family residences, strip commercial and apartment mixed
Two-story masonry apartment with separate laundry building	In complex with many similar units, neighborhood of single-family homes
Light industry/office, masonry/steel	Commercial section with warehouses and shops of similar type
Masonry/wood shop building, no heat system	Trailer court and strip commercial

(continued)

TABLE 4 (continued)

Buildings inspected	Surrounding buildings
Home converted to office, masonry	Single-family residence, strip commercial
Storage, showrooms and office, masonry/steel	Warehouse and light industry housed in similar buildings
Storefront office building with light industry and storage in rear, masonry and steel	Complex with many similar units
Nine-story building converted from apartments to office, textured ceiling material throughout	Commercial section most buildings of two-story variety, some residential single-family units
Masonry and steel structure with offices and cold storage facilities within	Warehouse district and light manufacturing, many buildings of similar size but older vintage
Single-story masonry and wood structure with office, shop, and storage	Typical of other commercial in area, also many single-family homes nearby
Single-story masonry and steel building	Relatively new area predominantly residential
Converted residence to office and storage	Residential area, some apartments, strip commercial
Cinderblock building adjoining open metal shed	Heavy industrial district with large utility buildings surrounding
Masonry structure with office space and laboratory facilities, four trailers attached, OOS	Residential area with light commercial in sections

TABLE 5. SOUTHEASTERN RURAL AREA

Buildings inspected	Surrounding buildings
One-story brick and glass with flat roof, some carpet, ceiling tile, forced warm air	Courthouse multistory stone, brick two-story stores, residential
Brick and glass utilitarian building, vinyl flooring, suspended ceilings, forced warm air	Cinderblock shops, wooden store, residential
Brick and glass two-story building built in 1970s newer type central heat, vinyl tile	Brick and wood residential, one-story, commercial
Brick single-story box construction, vinyl tile	Steel-shell warehouse, wooden commercial, residential
Masonry and stone, two-story, large open work area, interior central boiler, older style	Single-story commercial, brick and steel construction
Masonry and stone, two-story central boiler, older style, vinyl tile	Single-story brick stores, two-story stone government building, residential
Two-story brick and wood apartments, sprayed-on ceiling texture	Brick school, residential, other apartments of same type
Two-story brick apartments, vinyl flooring, individual unit heat	Large brick church, wooden residential
Two-story brick apartments, vinyl tile, carpeting, individual unit heat	Wood and brick, residential
Masonry building recently remodeled, suspended ceiling, carpeting	Single-story commercial and residential
Glass, wood, and brick store and distribution center, textured ceiling, vinyl flooring	Steel-shelled processing plant, wooden storage buildings
Steel and brick building, single-story suspended ceiling, vinyl flooring	Strip commercial, single-story, residential
Masonry and glass single-story, space heaters	Strip commercial, residential

(continued)

TABLE 5 (continued)

Buildings inspected	Surrounding buildings
Masonry and wood structure under renovation, vinyl floors	Single-story steel shell, farm buildings
Glass and masonry, single-story, suspended ceiling, space heaters	One- and two-story brick commercial, wooden residential
Wooden single-story, vinyl floor, textured ceiling	Wooden storage buildings, steel sheds
Wood, glass, and brick, single-story, vinyl floor	Farmland, woodland
Brick facade church with two additions, single-story, vinyl floor	Brick multifamily residential
Brick and wood, two-story, recent renovation, suspended ceiling, new heating system	Steel shell warehouse area, single-story commercial
Three-story brick and wood building, older style central boiler, suspended ceiling/tiles	Two-story commercial and brick office buildings

TABLE 6. WESTERN URBAN AREA

Buildings inspected	Surrounding buildings
One-story brick, vinyl tile, suspended ceiling	Single story commercial and residential
Single story masonary, vinyl tile, suspended ceiling	Park, residential area
Brown two-story stone, vinyl tile, suspended ceiling	Commercial area
Four-story white brick, vinyl tile, acoustical tile, asbestos pipe wrap (previously sampled and marked)	Brick Naval Hospital
One-story stone building, vinyl tile, suspended ceiling tile	School, residential neighborhood
Five-story stone and brick, suspended tile, fire proofing above ceiling tiles	Several story commercial buildings
Five-story stone and brick apartments; carpet, vinyl tile, plaster ceilings	Other similar apartments
Two-story adobe bachelor apartments; carpet, vinyl tile, plaster ceiling	Residential homes
Two-story garden apartments, vinyl tile, carpet, sprayed on ceiling	Residential homes
Two-story garden apartments, wood floors, plaster ceilings, own heat unit	Other similar two-story apartments
Two-story adobe garden apt., vinyl tile, sprayed on ceilings	Residential homes and apartments
Two-story adobe apts., vinyl tile carpet, sprayed on ceiling	Residential homes
Single story brick and wood warehouse, concrete floors and steel framed ceiling	One and two story brick commercial buildings

TABLE 6. WESTERN URBAN AREA (CONTINUED)

Buildings inspected	Surrounding buildings
Single story cinder block, concrete floors, blanket insulation on ceiling	Single story commercial buildings
Two story brick, artist in residence building, vinyl tile, plaster ceiling	Brick warehouses
One story stone warehouse, concrete floor, blanket fiberglass insulation on ceiling	Commercial buildings and warehouses
Single story, vinyl tile, suspended ceiling	Single story commercial buildings
Single story workshop, concrete floor and ceiling	Nothing
Single story brick, vinyl tile and ceiling tile in offices, concrete floor in work space	Single story commercial building
Single story aluminum, carpet and ceiling tile in offices, concrete floor in work space, air system in loft above offices	Single family residence, brick
Single story brick, vinyl tile and ceiling tile in offices, concrete floor in workspace	Single story brick commercial bldg.
Single story brick, vinyl tile, carpet, and suspended ceiling	Single story brick shopping center
Single story brick building, garage doors in front, concrete floors and steel beamed ceiling	Warehouses

TABLE 7. MIDWESTERN RURAL AREA

Buildings inspected	Surrounding buildings
Single story brick, carpet, suspended ceilings	Brick commercial bldg., wooden residentail homes
Single story brick, vinyl tile, suspended ceiling	Single story brick commercial, residences
Single story brick and glass, vinyl tile, suspended ceiling	Commercial
Three story stone, vinyl tile, plaster ceiling	Wood and brick residences
Single story brick and natural finish, partial basement, carpet, suspended ceiling, sprayed on ceiling in one office	Wood and brick residences
Single story brick and aluminum, vinyl tiles, suspended ceiling	Brick commerial bldgs.
Three story brick and wood apts., carpet, some vinyl tile, plaster ceilings, individual air system	Similar apts., single family residences
Six story brick retirement home, carpet, vinyl tile, sprayed on ceiling, common air system in basement	Single family wood and brick residences
Three story brick and wood apts., vinyl tile, plaster ceilings	Similar apts., part of a complex
Six story brick hotel that is mostly rented monthly, carpet, some vinyl tile, suspended and plaster ceiling. Common boiler in basement	Several story commercial bldg.
Three story wooden apts., vinyl tile, plaster ceilings, individual air systems	Similar apt. bldgs., single family residences

TABLE 7. MIDWESTERN RURAL AREA (CONTINUED)

Buildings inspected	Surrounding buildings
Two story brick and wood apts., carpet, plaster ceilings	Similar apts., single family residences, wood and brick
Single story brick with partial basement, carpet and suspended ceiling	Brick commercial buildings
Steel framed building, blanket insulation in warehouse	Open fields
Single story stucco building with partial basement, concrete floors, tiled ceiling	Grain elevators
Single story cinder block, vinyl tile, plaster ceiling	Highways, brick homes
Single story brick, vinyl tile, suspended ceiling	Part of a brick mall
Brick building with decorative roof, carpet, vinyl tile in basement, tiled ceiling	Brick residences
Steel framed warehouse, blanket insulation, suspended ceiling	Open fields
Single story cinderblock structure, concrete floor and ceiling	Single family residence, wood and brick
Steel framed building, blanket insulation in garage, tile in office	Open fields
Single story cinderblock building, vinyl tile and suspended ceiling	Brick commercial buildings
Wooden barn-like building, wooden floors and ceiling	Brick and wood commercial buildings

TABLE 8. MIDWESTERN URBAN AREA

Buildings inspected	Surrounding buildings
Brick building, vinyl tile, ceiling tile	Brick residential homes
Masonary structure, concrete floors and ceilings	Similar structures
Brick two-story structure, vinyl tile and ceiling tile in basement; concrete floor and ceiling on top floor.	Brick multi-floor hospital
35 story stone office building, ornate towers on top, vinyl tile and marble floors, tiled ceiling	Large stone office buildings
Three story glass and metal paneled building; vinyl tile throughout, mineral wood covered as ceiling; fire proofing sprayed in attic	Brick commercial buildings
Eight story stone building with columns in front, vinyl tile throughout, suspended ceilings in offices	Large stone commercial buildings
Three story brick apts., one central boiler, carpet, sprayed on ceilings	Similar brick apts., brick residential homes
Recently renovated 4 story brick apts., wooden floors, sprayed on ceilings, boiler in basement	Brick homes
Three story renovated brick apts., wooden floors, sprayed on ceilings, boiler in basement	Brick homes
Four story brick apts., carpet, sprayed on ceiling, boiler in basement	Multi-story brick apt. buildings
Three story wood apt., individual air systems, carpet and sprayed on ceilings	Similar wood apts.
Three story brick colonial apts., central air system, carpet, sprayed on ceiling	Brick apts. and residential homes

TABLE 8. MIDWESTERN URBAN AREA (CONTINUED)

Buildings inspected	Surrounding buildings
Single story concrete structure; Concrete floor and ceiling	Brick commercial buildings
Two story brick; residence upstairs; vinyl tile; sprayed on ceiling	Wood and brick single family residences
Single story brick building; carpet; suspended ceiling	Part of a brick shopping center
Single story brick building; carpet; suspended ceiling	Part of a brick shopping center Brick commercial buildings
Single story cinderblock building; linoleum; suspended ceiling	Brick commercial and residential buildings
Two story brick warehouse; carpet and ceiling tile in office; concrete floor and ceiling in warehouse.	Brick commercial buildings
Single story cinderblock structure; vinyl tile; suspended ceiling	Brick commercial buildings
Single story brick building; vinyl tile; suspended ceiling	Part of a brick shopping center
Single story cinderblock structure; vinyl tile; suspended ceiling	Brick and wood single family residences
Old wood house converted to office; vinyl tile; ceiling tile	Brick and wood single family residences
Single story brick office building; vinyl tile; ceiling tile	Brick single family residences

TABLE 9. NORTHEASTERN URBAN AREA

Buildings inspected	Surrounding buildings
Large stone monument; marble floors; decorative ceilings	Park; brick single family residences
Three story circular brick building; vinyl tile; suspended ceilings	Brick commercial buildings
Seven story brick building; vinyl tile and carpet; suspended cielings	Brick commercial buildings
Six story ornate stone building; vinyl tile and concrete floors; decorative ceiling	Brick commercial buildings
Multi-story brick; vinyl tile suspended ceilings; sparyed on material in one area that had been encapsulated	Brick single family residences
Multi-story panel and glass building; carpet; suspended ceilings; fire-proofing above ceiling	Brick commercial buildings
Eight story brick apartments; vinyl tile and wood floors; plaster ceiling; common boiler in basement	Brick public housing complex
Seven story brick apartments; commercial stores on 1st floor; vinyl tile and wood floors; plaster ceilings. Common boiler in basement	Brick commercial and residential buildings
Seven story brick apartments; vinyl tile; plaster ceilings; common boiler in basement.	Several story brick residences
Three story brick apartments; hardwood floors; plaster ceilings; common boiler in basement	Brick residences
Several story brick; hardwood floors; plaster ceilings; common boiler in basement	Brick public housing complex
Seven strory brick apartments; hardwood floors; plaster ceilings common boiler in basement	Similar apartment buildings

TABLE 9. NORTHEASTERN URBAN AREA (CONTINUED)

Buildings inspected	Surrounding buildings
Five story brick; hardwood floors; decorative tin ceilings	Several story brick commercial buildings
Seven story brick hotel; carpet and plaster ceilings in hotel; some rented offices have vinyl tile and ceiling tile	Brick commercial buildings
Seven story brick building; vinyl tile and concrete floors; plaster ceilings	Brick commercial buildings
Two story brick; vinyl tile and wood floors; ceiling tile	Brick commercial buildings
Four story brick building; concrete floor and ceiling in work area; carpet and suspended ceilings in offices	Brick commercial buildings
Three story brick building; concrete and hardwood floors; high ceilings	Brick commercial warehouses
Four story brick building; vinyl tile; ceiling tile	Brick commercial buildings
Ten story brick office building; carpet and vinyl tile; suspended ceilings	Several story brick commercial buildings
Multi-story brick hotel; several sub-basements included in this; carpet; sprayed on ceiling in rooms and used for decoration	Several story brick commercial buildings
Five story brick building; hardwood floors; decorative tin ceilings	Several story brick commercial buildings
Three story brick warehouse; concrete floor; high ceiling	Brick commercial warehouses

TABLE 10. SOUTHWESTERN URBAN AREA B

Buildings inspected	Surrounding buildings
Single story brick and stone building; vinyl tile; suspended ceiling	Brick commercial buildings
Two story brick; vinyl tile, suspended ceiling and some sprayed on material	Brick commercial buildings
Single story wood paneled building; asphaltic tile, suspended ceiling	Stone and brick buildings
Multi-story stone and glass building; vinyl tile and carpet; suspended ceilings; sprayed on fire-proofing above ceiling	Stone and brick buildings
Single story brick structure; vinyl tile: suspended ceiling	Brick and wood residences
Single story brick structure; asphaltic tile; suspended ceiling	Brick and aluminum commercial buildings
Two story brick apartments; carpet and vinyl tile; plaster ceilings; individual air system	Similar brick apartment buildings
Two story brick apartments; carpet; plaster ceilings; individual air system	Similar apartment buildings
Two story brick apartments; carpet and linoleum; plaster ceilings; individual air system	Similar apartment buildings
Three story brick apartments; carpet; sprayed on ceilings; two hot water heaters provide heat	Similar apartment buildings
Two story brick apartments; carpet plaster ceilings; individual air system	Similar apartment buildings
Metal building with concrete floor and metal ceiling; vinyl tile and ceiling tile in office	Brick and wood residences
Single story cinderblock building; concrete floors and ceilings	Brick school and wood residences

TABLE 10. SOUTHWESTERN URBAN AREA B (CONTINUED)

Buildings inspected	Surrounding buildings
Small metal structure; concrete floors; metal ceiling	Wood single family residences
Single story brick warehouse; Concrete floor and ceiling in warehouse; vinyl tile and suspended ceiling in office	Brick commercial warehouses
Single story brick structure; carpet; suspended ceilings; electric air system on roof	Part of a shopping mall
Six story modern brick building; carpet; ceiling tile; boiler in basement	Brick commercial buildings
Single story brick; concrete floors; ceiling tile	open woods
Single story brick and wood building; carpet and vinyl tile; plaster ceiling	Brick single family residences
Single story brick building; recently remodeled; floor tile and suspended ceiling	Part of a brick shopping plaza
Single story brick building; vinyl tile; suspended ceiling	Apartments and commercial buildings
Single story brick building; vinyl tile; suspended ceiling	Brick and wood single family residences

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15. Supplementary Notes

16. Abstract (Limit: 200 words)

A nationally representative sample of 231 buildings at 10 sites were inspected for potentially asbestos-containing materials. Bulk samples (1,510) were taken and analyzed by Polarized Light Microscopy. Estimates were made of the number and percent of buildings with asbestos-containing friable materials, the square footage of such materials, and the percent asbestos content of the materials. Principal findings include the following statements: 20 percent (733,000) of all buildings have some asbestos-containing friable material (ACFM) -- sprayed-on or trowelled-on material, pipe or boiler insulation, or ceiling tile; 5 percent (192,000) of all buildings have sprayed-on or trowelled-on ACFM. The average percent asbestos content is 14 percent. Eighteen percent (64,000) of residential apartment buildings have sprayed-on or trowelled-on ACFM. The average percent asbestos content is 9 percent. One-tenth of one percent of ceiling tile contains asbestos and it contains a very low percentage on average (3%). In buildings constructed prior to 1960, ACFM was concentrated primarily in pipe and boiler insulation; in buildings constructed between 1960 and the early 1970's, ACFM was concentrated primarily in sprayed-on or trowelled-on materials. In 1973, EPA banned the use of asbestos thermal and acoustical insulation materials except for decorative purposes, and in 1978 EPA banned them for all purposes.

17. Document Analysis a. Descriptors

Asbestos, asbestos in buildings, asbestos sampling, ceiling tile, Government buildings, PLM, private buildings, residential buildings, survey design

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